Forest Products Journal

MEASURING ADHESION OF SURFACE COATINGS—p. 23

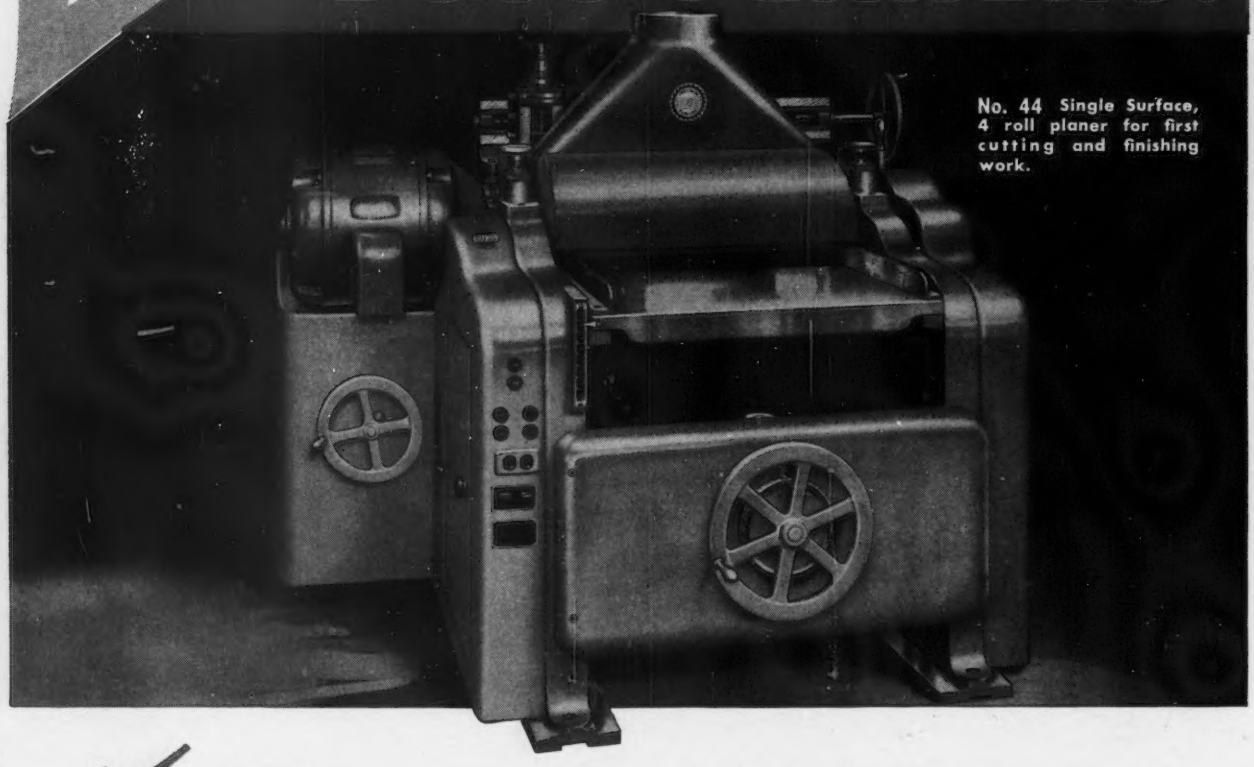
How effective are dip treatments for wooden boxes? Long-term Army-Forest Service findings start on p. 1.

Published by the FOREST PRODUCTS RESEARCH SOCIETY BOX 2010 MADISON 5, WISCONSIN

Check the Record!

THE BEST PLANER FEATURES ARE FOUND FIRST IN . . .

BUSS PLANERS!



No. 44 Single Surface, 4 roll planer for first cutting and finishing work.

In 1919 BUSS pioneered the use of *High Speed Ball Bearings in planers;* 1922, *Direct Motor on the Arbor Cutterhead Construction;* 1923, *Drop-Forged Sectional Chipbreaker and Roll;* 1925, *Multi-Speed Motor and High Frequency;* 1930, *Chrome Plated Wearing Surfaces;* 1935, *Built-in Reduction Unit,* eliminating fast-running gears; 1941, *Pressure Bar Micrometer Control* (patented); 1946, *Instantaneous Lower Roll Micrometer Adjustment;* 1948, *Shearing Bar* (patented); 1950, *Chipbreaker Micrometer Control* for adjustment of chipbreaker (patented); 1956, *Commercial production of 59" wide Double Surfacer;* 1950-58 *Special Production Surfacers.*

All the above are exceedingly valuable developments as proven in actual production and were *found first in BUSS planers.* Consequently, to be sure the planer you buy today is modern to the minute with all the features necessary to produce the most and the best planing at lowest cost, be sure it is a BUSS Planer. Write for bulletins or consult us and judge for yourself.

6 MODELS
40 SIZES

THERE'S A BUSS PLANER TO EXACTLY SUIT YOUR NEEDS

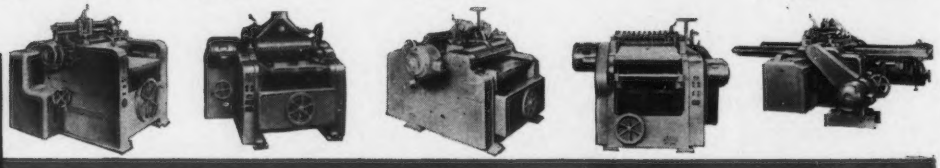
No. 4-L Single Surface, medium sized planer for first cutting and finishing work.

No. 44 Single Surface, 4 roll planer for first cutting and finishing work. **No. 66** — 6 roll.

No. 88 Double Surface, 8 roll planer for first cutting and finishing work.

No. 55 Heavy duty Double Surfacer for planing rough lumber.

MICRO-SURFACER for planing hardwood and other very thin materials.



BUSS
SINCE 1862
MACHINE WORKS

PLANER SPECIALISTS EXCLUSIVELY

FOR A LIMITED TIME ONLY, TO REDUCE OUR INVENTORY

Important Savings

IN PRICES OF BACK ISSUES OF FPRS PUBLICATIONS

1. ANY SINGLE COPY ANNUAL PROCEEDINGS, 1947–1954 . . .

Each volume ranges from 286 to 607 pages and sold originally from $5.00 to $10.00. Each contains all of the published National Meeting papers for that year, covering a general cross-section of modern wood technology. (Volumes 1947 through 1951 are cloth-bound. Volumes 1952–54 are paper-bound and were originally issued as Journals in that year.) Annual Index contained in December issue.

$2.00
POST PAID ANYWHERE

2. 12 ISSUES FOREST PRODUCTS JOURNAL, 1956 OR 1958 . . .

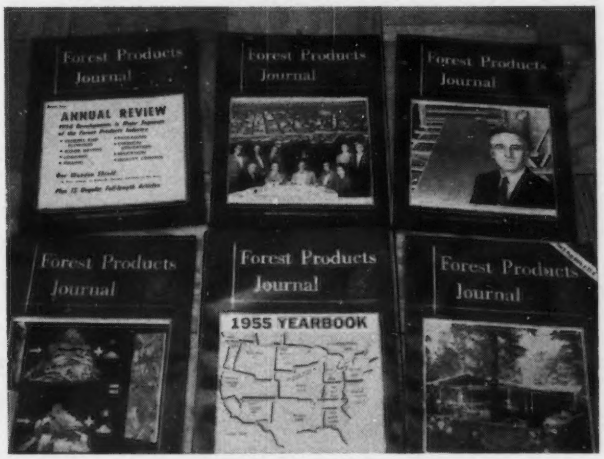
Originally to obtain these Journals you would have had to pay $15.00. Today you can complete your library for just 1/3 of the original price. The 12 issues for each year contain from 964 to 1046 pages of information covering modern wood technology. Annual Index appears in December issue.

$5.00
POST PAID ANYWHERE

INCOMPLETE SET 1957 (11 ISSUES) . . .

In 1957 the October "Yearbook" issue is out of print. The remaining 11 issues, or a total of some 900 pages, are available at a considerable savings over original cost. Annual Index appears in December issue.

$4.00
POST PAID ANYWHERE



3. ALL 6 ISSUES JOURNAL 1954 OR 1955 (5 ISSUES 1953) . . .

In these years the Society published fewer issues of the Journal but more pages per issue (736 to 852). Original cost $15.00 . . . now available at but a fraction of this price. Annual Index appears in December issue.

$4.00
POST PAID ANYWHERE

To: Forest Products Research Society
417 North Walnut Street
Madison 5, Wisconsin

Yes! Send me the following Proceedings or Journal sets. I am enclosing check or money order to cover same.

- ☐ 1947 Proceedings -- $2.00
- ☐ 1948 Proceedings -- $2.00
- ☐ 1949 Proceedings -- $2.00
- ☐ 1950 Proceedings -- $2.00
- ☐ 1951 Proceedings -- $2.00
- ☐ 1952 Proceedings -- $2.00
- ☐ 1953 Proceedings -- $2.00
- ☐ 1954 Proceedings -- $2.00
- ☐ 1953 set of Journals -- $4.00
- ☐ 1954 set of Journals -- $4.00
- ☐ 1955 set of Journals -- $4.00
- ☐ 1956 set of Journals -- $5.00
- ☐ 1957 set of Journals -- $4.00
- ☐ 1958 set of Journals -- $5.00

Total Enclosed $_____

Name _____

Firm _____

Street _____

City _____ State _____

PRICE LIST

INDIVIDUAL COPIES OF FPRS PUBLICATIONS

FOREST PRODUCTS RESEARCH SOCIETY — **417 N. WALNUT ST., MADISON, WIS.**

ANNUAL PROCEEDINGS

(Cloth Binding)

- ☐ Vol. 1, 1947 344 pages ---------- $2.00
- ☐ Vol. 2, 1948 500 pages ---------- $2.00
- ☐ Vol. 3, 1949 607 pages ---------- $2.00
- ☐ Vol. 4, 1950 506 pages ---------- $2.00
- ☐ Vol. 5, 1951 400 pages ---------- $2.00

FOREST PRODUCTS JOURNAL

(Paper Binding)

Volume I, 1951

- ☐ No. 1, September ---------- $1.00

Volume II, 1952

- ☐ No. 1, April ---------- Out of print
- ☐ No. 2, June ---------- Out of print
- ☐ No. 3, September ---------- Out of print
- ☐ No. 4, November ---------- $1.00
- ☐ No. 5, December, Annual Proceedings ------ $2.00

Volume III, 1953

- ☐ No. 1, February ---------- $1.00
- ☐ No. 2, June ---------- $1.00
- ☐ No. 3, September ---------- $1.00
- ☐ No. 4, November ---------- $1.00
- ☐ No. 5, December, Annual Proceedings ------ $2.00

Volume IV, 1954

- ☐ No. 1, February ---------- $1.00
- ☐ No. 2, April ---------- $1.00
- ☐ No. 3, June ---------- $1.00
- ☐ No. 4, August ---------- $1.00
- ☐ No. 5, October, Annual Proceedings -------- $2.00
- ☐ No. 6, December ---------- $1.00

Volume V, 1955

- ☐ No. 1, February ------- $1.00
- ☐ No. 2, April ---------- $1.00
- ☐ No. 3, June ---------- $1.00
- ☐ No. 4, August -------- $1.00
- ☐ No. 5, October, Yearbook $2.00
- ☐ No. 6, December ------ $1.00

Volume VI, 1956

- ☐ No. 1, January -------- $1.00
- ☐ No. 2, February ------- $1.00
- ☐ No. 3, March --------- $1.00
- ☐ No. 4, April ---------- $1.00
- ☐ No. 5, May ---------- $1.00
- ☐ No. 6, June ---------- $1.00
- ☐ No. 7, July ---------- $1.00
- ☐ No. 8, August ---------- $1.00
- ☐ No. 9, September ---------- $1.00
- ☐ No. 10, October, Yearbook ---------- $2.00
- ☐ No. 11, November ---------- $1.00
- ☐ No. 12, December ---------- $1.00

Volume VII, 1957

- ☐ No. 1, January ---------- $1.00
- ☐ No. 2, February ---------- $1.00
- ☐ No. 3, March ---------- $1.00
- ☐ No. 4, April ---------- $1.00
- ☐ No. 5, May ---------- $1.00
- ☐ No. 6, June ---------- $1.00
- ☐ No. 7, July ---------- $1.00
- ☐ No. 8, August ---------- $1.00
- ☐ No. 9, September ---------- $1.00
- ☐ No. 10, October, Yearbook ---------- Out of print
- ☐ No. 11, November ---------- $1.00
- ☐ No. 12, December ---------- $1.00

Volume VIII, 1958

- ☐ No. 1, January ---------- $1.00
- ☐ No. 2, February ---------- $1.00
- ☐ No. 3, March ---------- $1.00
- ☐ No. 4, April ---------- $1.00
- ☐ No. 5, May ---------- $1.00
- ☐ No. 6, June ---------- $1.00
- ☐ No. 7, July ---------- $1.00
- ☐ No. 8, August ---------- $1.00
- ☐ No. 9, September ---------- $1.00
- ☐ No. 10, October, Yearbook ---------- $2.00
- ☐ No. 11, November ---------- $1.00
- ☐ No. 12, December ---------- $1.00

Delivery charges will be paid if remittance in full is received with order.

ORDER FORM

Forest Products Research Society
417 North Walnut Street
Madison 5, Wisconsin

Date ----------

Please send me copies of the publications checked above. Remittance of $---------- is enclosed in payment.

Name ----------

Company ----------

Address ----------

City ---------- Zone ------ State ----------

(Please type or print)

Note: All prices quoted include prepaid postage.

FPRS

Executive Officers

President
W. Jeter Eason, Memphis, Tenn.

President-Elect
E. S. Harrar, Durham, N. C.

Vice President
R. H. Berry, Burney, Calif.

Past President
F. H. Kaufert, St. Paul, Minn.

Executive Secretary
Frank J. Rovsek, Madison, Wis.

•

Regional Board Members

Southeast
W. L. Irwin, Pickens, S. C.

South-Central
W. R. Warner, Warren, Ark.

Northeast
D. K. Saunders, Westbrook, Me.

North-Central
J. J. Allegretti, Chicago, Ill.

Northwest
T. S. Veazey, Jr., Butte, Mont.

Southwest
F. E. Dickinson, Richmond, Calif.

•

Publications Committee

Chairman
Edward G. Locke, Madison, Wis.

•

Editorial Staff

Editor
R. H. Hamre, Madison, Wis.

Editorial Assistant
Sandra M. Parrini

THE FOREST PRODUCTS JOURNAL is published monthly by the Forest Products Research Society, P. O. Box 2010, University Station, Madison 5, Wisconsin. Second-class postage paid at Madison, Wisconsin.

Annual subscription rate, $15.00; single copies $1.00, except October Yearbook Number, $4.00. Annual subscription rate is $11.25 with voting, associate, and supporting memberships in the Society. Remittances should be made payable to the Forest Products Research Society.

Correspondence on editorial matters should be addressed to the Editor, at the Executive Office. The Society is not responsible for views expressed in publications.

FOREST PRODUCTS JOURNAL

Vol. IX, No. 1 January, 1959

CONTENTS

Page

FPRS News–Digest 5-A

WOOD PRESERVATION

Preservative Water-Repellent Treatments for Wood Packing Boxes.....*A. F. Verrall* 1
Three-minute dips protected boxes 3 to 5 years against decay; soil poisons were needed to stop termites.

FINISHING

New Tool for Measuring Adhesion of Coatings to Wood.....*G. E. Naslund and B. O. Hallberg* 23
A pressure-sensitive tape is stripped from a painted wood surface by a self-recording pendulum.

WOOD DRYING

Bound-Water Diffusion Into Wood in the Fiber Direction.....*A. J. Stamm* 27
Moisture moves in wood in 3 ways. One was isolated for study here to exclude effects of inter-relationships.

Highlights Leading Up to Modern Kiln Drying.....*H. D. Tiemann* 11-A
The history of artificial wood drying is traced in Mr. Tiemann's Charles J. Williams Memorial Seasoning Lecture.

TESTING

Zero Shift of Bonded Electrical Resistance Strain Gages on Wood...*A. Sliker* 33
Concentration of heat in the gage may cause errors. Ways to minimize this source of error are suggested.

PULPWOOD

Volumetric Method of Determining Dry Weight of Green Aspen Bolts.....*J. Haygreen* 38
With conversion factors presented, dry weight can be determined accurately from measurements of volumetric displacement.

MATERIALS HANDLING

Factors Involved in Lumber Packaging for Rail Shipment.....*J. Buchálter* 15-A
A proposed method of package loading is described and compared with other existing packaging and loading systems.

GLUES AND GLUING

A Progress Report on Laminating in Canada.....*R. F. DeGrace* 18-A
Most significant is the Qualification Code developed by CITC for Manufacturers of Structural Glued-Laminated Timber.

Durable, Structural Components of Casein Nail-Glued Wood...*D. H. Percival* 21-A
After open exposure testing, the author recommends casein glue as best for fabricating nail-glued trusses.

DEPARTMENTS

Employment Opportunities..... 10-A
World-Wide Forest Products News..... 23-A
"Briefing" FPRS Papers
Fiberboard Panel Discussion, Upper Mississippi Valley Section Meeting 25-A
Unit Car Loading.....*J. Brelsford* 27-A
Abstracting the Literature..... 28-A
Index to Advertisers.....3rd Cover

IMPORTANT FPRS DATES

Feb. 20–21, 1959: Rocky Mountain Section Meeting, Ft. Collins, Colo.

April, 1959: Ohio Valley Section Meeting, New Albany, Indiana.

April 14–15, 1959: Joint Inland Empire Section—Northwest Wood Products Clinic Meeting, Spokane, Wash.

May 25–26, 1959: Joint Eastern Canadian—Northeast Spring Section Meeting, Ottawa, Ontario.

June 28–July 3, 1959: Thirteenth National Meeting, San Francisco, Calif.

Send A Copy To A Friend

Forest Products Research Society
Box 2010, University Station
Madison 5, Wisconsin

Please send a free copy of FOREST PRODUCTS JOURNAL with my compliments to the persons listed below:

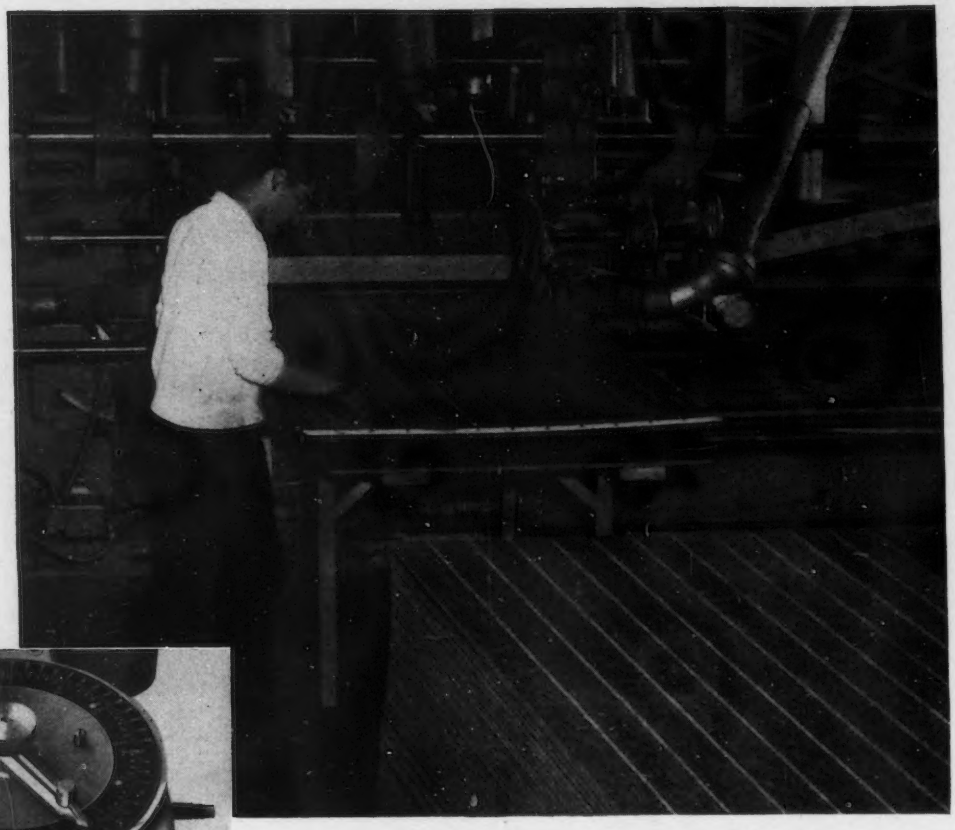
To _____
Address _____
City _____ Zone __ State ____

Sender _____
Address _____
_____

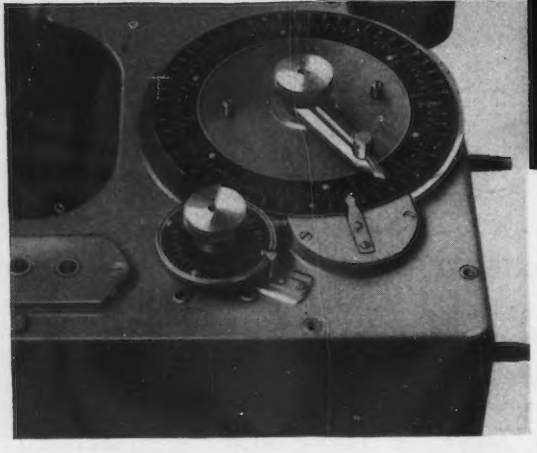
Versatile

GREENLEE No. 545 Specialty Machine Cuts Timblend and Plywood Specialties

at RODDISCRAFT, INC. ARCATA, CALIFORNIA



Column adjustments are power operated and easily made. The *precise* distance between cutters is registered on the two dials shown below. The large one shows settings in feet and inches . . . the smaller one in sixty-fourths.

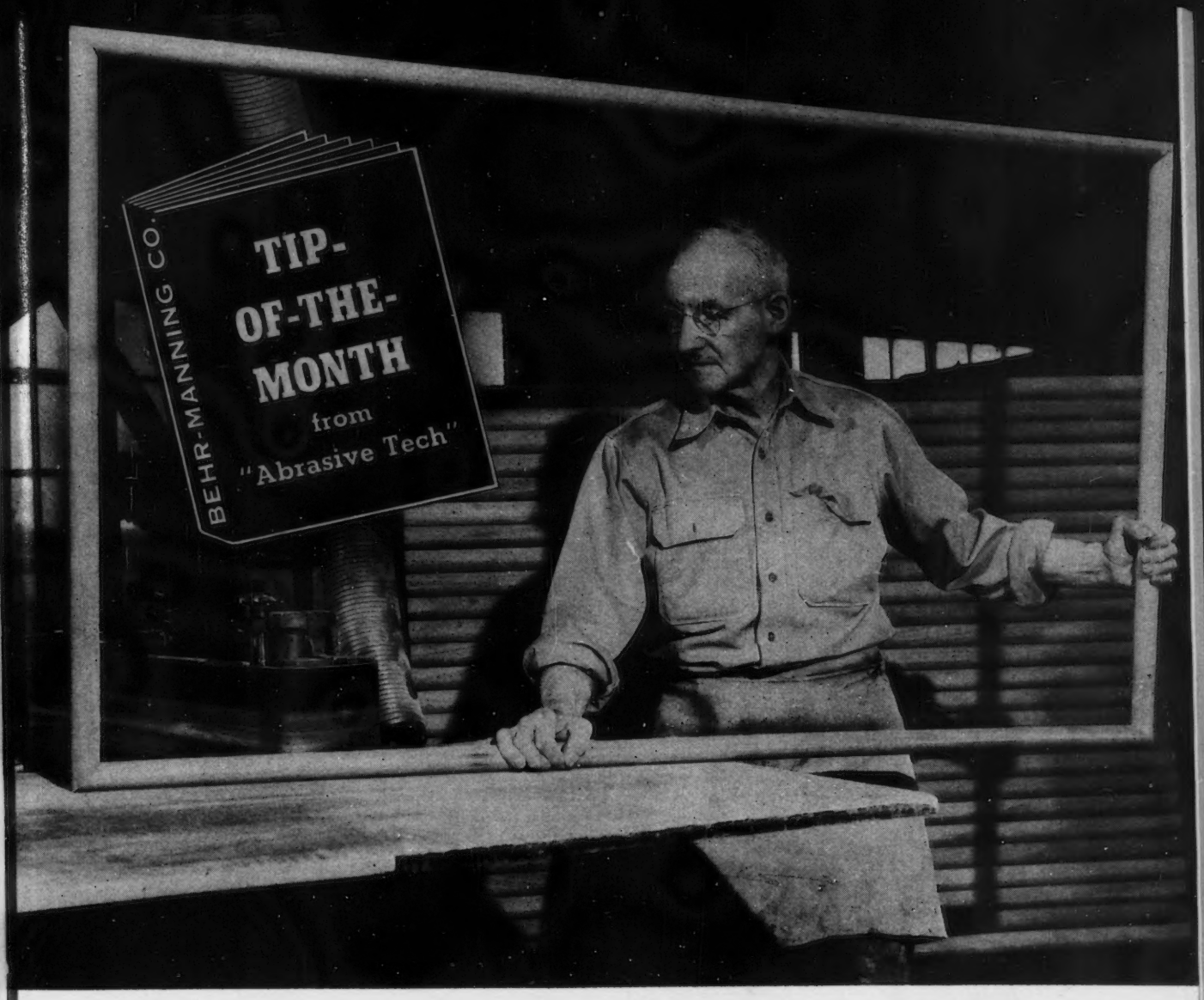


Trimming Timblend . . . splitting plywood . . . running Texture 1-11 and other grooved patterns . . . scarfing . . . edge-shaping . . . it's all in the day's work for this Greenlee No. 545. Here, more than 300 4′ x 8′ Texture 1-11 panels are machined each hour. Greenlee's arrangement of steady-bearings and hold-downs enables mounting grooving cutters on 2″ as well as 4″ centers. Investigate the versatile Greenlee Double-End Machines.

WOODWORKING MACHINERY MANUFACTURERS' ASSOCIATION WMMA

GREENLEE BROS. & CO.

1709 TWENTY-FIRST AVE.
ROCKFORD, ILL.



Fast polishing of mirror frames with edge sander

Behr-Manning methods engineers are always seeking and developing improved techniques, ways to speed production and reduce costs . . . such as the simple application of an edge sander equipped with a graphite and canvas covered noseblock to polish solid mahogany mirror frames. Here a 3/0 Garnet Paper Belt oscillates up and down to distribute wear across the surface.

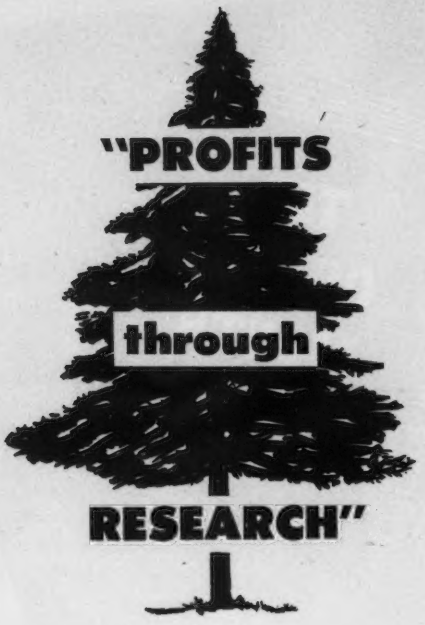
Can a Behr-Manning methods engineer save *you* time and material? Just phone our nearest branch for a date. There are 17 well-equipped "Abrasive Tech" Methods Rooms ready to help solve problems or demonstrate new techniques in: Atlanta, Boston, Buffalo, Chicago, Cincinnati, Cleveland, Detroit, Grand Rapids, High Point, Indianapolis, Los Angeles, Teterboro, Camden, San Francisco, Seattle, St. Louis, and Brantford, Canada. Main office and plant: Troy, N. Y.

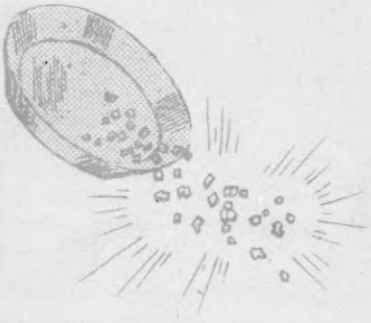
BEHR-MANNING CO.
TROY, NEW YORK
A DIVISION OF NORTON COMPANY NORTON ABRASIVES®

IW-1

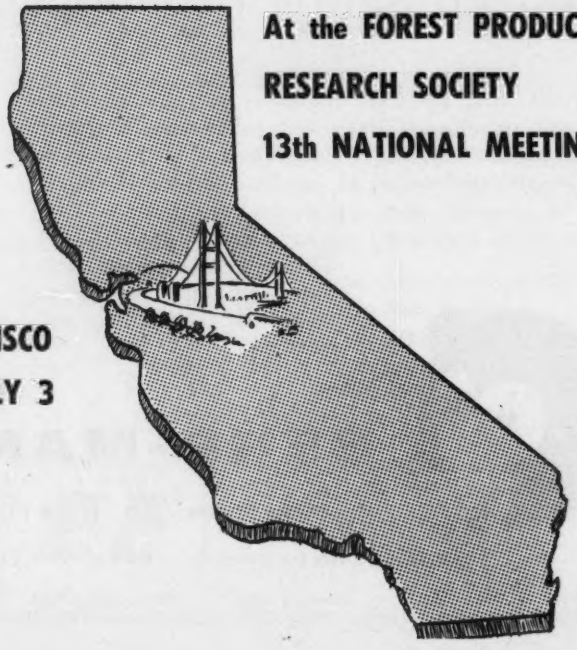
In Canada: Behr-Manning (Canada) Ltd., Brantford. For Export: Norton Behr-Manning Overseas Inc., Troy, N. Y., U.S.A.

BEHR-MANNING PRODUCTS: Coated Abrasives • Sharpening Stones • Pressure-Sensitive Tapes NORTON PRODUCTS: Abrasives • Grinding Wheels • Grinding Machines • Refractories • Electrochemicals





Strike it Rich!



At the FOREST PRODUCTS RESEARCH SOCIETY 13th NATIONAL MEETING

In Fabulous SAN FRANCISCO
JUNE 28-JULY 3

Make a Date
at the Golden Gate
June 28 – July 3

FPRS News-Digest

"Research for Profit" 1959 Meeting Theme

20 Technical Sessions, Table-top Exhibit to be Featured at June 28–July 3, FPRS National Meeting

The St. Francis Hotel in San Francisco will be the site of the FPRS Thirteenth National Meeting, June 28–July 3, 1959, according to General Chairman, Raymond H. Berry. Theme of the meeting is "Research for Profit".

Main attraction will be the 20 technical sessions presented by the 14 Divisions of the Society. The economic implications of research results will be emphasized, Dr. E. S. Harrar, President-Elect and chairman of the technical sessions, reported at the January Executive Board Meeting. The sessions are scheduled as follows:

Monday a.m., June 29
Session 1, Wood Composition Board
Session 2, Veneer and Plywood
Session 3, Wood Machining
Monday p.m.
Session 4, Glues and Gluing
Session 5, Chemical Utilization
Session 6, Wood Preservation
Tuesday a.m., June 30
Session 7, Logging
Session 8, Wood Drying
Session 9, Wood Finishing
Tuesday p.m.
Session 10, Lumber Manufacturing
Session 11, Wood Finishing (2)
Session 12, Packaging
Wednesday a.m., July 1
Session 13, Joint Lumber Manufacturing and Wood Drying
Session 14, Glues and Gluing (2)
Session 15, Industry-Education
Thursday a.m., July 2
Session 16, Merchandising
Session 17, Chemical Utilization (2)
Session 18, Technical General Session
Thursday p.m.
Session 19, Wood Composition Board (2)
Session 20, Quality Control

Industry Exhibits Planned This Year

An important addition this year will be the booth and table-top wood industry exhibits. The display area will be on the second floor of the St. Francis Hotel, adjacent to technical session meeting rooms. Exhibit chairman Victor Roth reports the exhibits will open Sunday, June 28, and continue throughout the week.

Shown will be portable equipment, products, and photographic displays. A booth 8 by 8 feet rents for $200, and an 18 by 16 inch table top for $75.

AERIAL VIEW of San Francisco. Background bridge, Golden Gate; foreground bridge, Oakland; Island in Bay, Alcatraz.

Registration Begins Sunday

Registration will begin 1:30 p.m., Sunday, June 28, and continue throughout the week. Fees of $12.00 for members and $14.00 for nonmembers will include admission to all technical sessions, Division and committee meetings. Women's registration fee is $6.00.

AIWE to Meet

FPRS activities on Sunday will include afternoon meetings of the National Executive Board, the Employment Committee, the Membership Committee, and the Publications Committee. The AIWE will also meet.

Official Luncheon Planned for June 30

A speaker of national importance will be featured at the Official Luncheon scheduled for noon on Tuesday, June 30. The speaker will be announced in forthcoming months.

Plant Tours

Plant trips to suit a wide variety of interests are planned for the latter part of the convention week. On Thursday, July 2, trips are scheduled to Fibreboard Products Corp., Antioch; Michigan–California Lumber Co., Camino; and the University of California Forest Products Laboratory, Richmond.

On Friday, July 3, three all-day trips will be available to registrants. They are Union Lumber Co., Ft. Bragg; Masonite Corp., Ukiah; and Diamond Gardner Corp., Red Bluff. Trips to other plants and facilities in the area can be arranged upon request.

Social Activities

A reception for all those attending the meeting will be held on Sunday evening, June 28, to provide an opportunity for registrants to meet old friends and make new ones. The Northern California Section of the Society will be host to registrants and their families at this event.

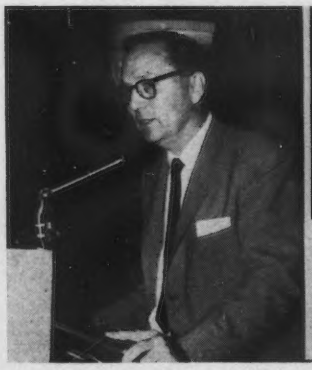
A cocktail cruise around San Francisco Bay is planned for the Paul Bunyan hour on Tuesday evening, June 30. The traditional FPRS Party will be held on Wednesday evening, July 1, at the California Mural Room of the St. Francis Hotel.

Women's Program

Among the highlights of the women's program will be a tour of San Francisco with stops at the exotic Japanese Tea Gardens, picturesque Fisherman's Wharf, and Chinatown. Also planned is a tour of San Francisco shops, a luncheon at the Canterbury Hotel with a showing of new styles, and a Decorator's Tour of Jackson Square, once part of the famous Barbary Coast.

SECTIONS *in the NEWS*

New Trends in Wood Use Theme of Northeast Meeting



NORTHEAST SECTION CHAIRMAN Eric Anderson at the Official Banquet during the Section's Oct. 30–31, 1958 meeting at Lancaster, Pa. "Trends in Wood Utilization" was the theme of the meeting.

AT THE BANQUET, H. W. Prentice, Jr., described Armstrong Cork Co. products. Plants visited were: Armstrong; De-Walt Div., American Machine & Foundry Co., Sensenich Corp., and Trojan Boat Co.

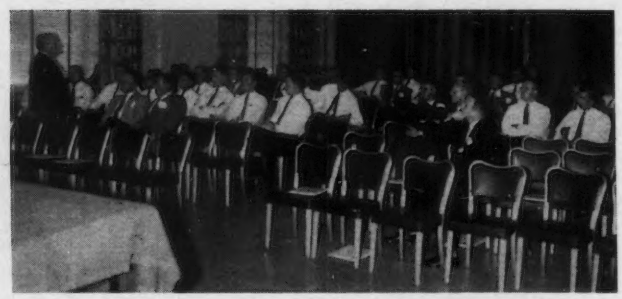
AT THE SPEAKERS TABLE during the banquet were (l. to r.): B. A. Jayne, Yale University; D. K. Saunders, Saunders Bros.; H. Neidermeyer, Sesenich Corp.; Eric Anderson (behind podium); H. W. Prentice, Armstrong Cork Co., and J. A. Hauter, Allan Products Co.

ON THE KILN DRYING PANEL were (l. to r.): Richard Elliott, Standard Dry Kiln Co.; William Delmhorst, Delmhorst Instrument Co.; S. D. Pryce, Jens Risom Design, moderator; Wallace Adams, Moore Dry Kiln Co., and Harold Gatslick, U. of Mass. Other discussions during the meeting centered around trends in wood combinations; furniture design, materials and methods; and hardwood utilization.

DURING THE PANEL on Wood Research (l. to r.): Dr. G. J. Stout, Penn. State U., discussed "Slab-space Heating for Basement-less Houses"; R. W. Davidson, N. Y. College of Forestry at Syracuse, talked on "Rheological Studies on Wood"; B. A. Jayne, Yale University was moderator; and W. A. Cote, Jr., N. Y. College of Forestry at Syracuse, spoke on "Applications of Electron Microscopy in Research".

Carolinas-Chesapeake Meeting Discusses "Wood and Water"

Over 100 persons attended the Carolinas-Chesapeake meeting, Nov. 7–8, 1958, at Charlotte, N. C. At the speakers' table during the session on "High Temperature Drying" were (l. to r.): W. W. Calvert, Ottawa FPL; C. A. Hart, N. C. State College; Howard Price, Coe Mfg. Co., Monie Hudson, Consultant; Harry Radden, Miller-Hofft Co., and R. L. Youngs, USFPL.



"Wood and Water" was the theme of the meeting. Several members of the Southeastern Dry Kiln Club participated in Technical Session III, which dealt with "General Wood Moisture Relations". More than 35 members of the Kiln club attended the FPRS meeting. Here, W. L. Irwin, Regional Board member, addresses registrants after Technical Session II.

Rocky Mountain Section to Meet Feb. 20–21, During Foresters' Day at Colorado

The Rocky Mountain Section will participate in Foresters' Day celebrations at Colorado State University, Feb. 20–21, Section officers reported recently. New wood utilization laboratory facilities will be dedicated the afternoon of Feb. 21, at the university.

FPRS will hold a technical session, Friday, Feb. 20. Society President Eason is expected to address the meeting. FPRS registrants will attend a keynote address for all professional groups meeting on the campus, before the technical session.

The Foresters' Days celebration at Colorado State University, during which the new laboratory facilities will be dedicated, marks the 50th year of Forestry training at the university. Theme for the festivities is "Educational and Resource Management Trends and Needs".

Use of Red Cedar Discussed At Pacific NW Oct. Meeting

Western Red Cedar utilization was one of the main topics of discussion at the Pacific Northwest meeting, Oct. 27–28, 1958, held at Vancouver, British Columbia, Section officers reported.

Increased utilization of cedar is largely dependent on finding new uses for it, according to C. B. Dunham, Canadian Chemical and Cellulose Co., who spoke on "Forestry Problems which Arise from Incomplete Cedar Utilization". He reviewed logging and log grading practices and the seriousness of decay in the standing timber.

C. F. McBride, Canadian FPL, discussed a recovery study at three sawmills in his paper on "Residues from Western Red Cedar Lumber and Shingle Mills". Results indicated that 18.7 per cent of the volume went into sawdust and the same volume into slabs, edgings, and trim.

According to James D. Wethern, Crown Zellerbach Corp., the chemical utilization of red cedar will be dependent on finding uses for the extractives. The species is pulpable, he said, by either the kraft or sulfite process.

"Particle Board from Cedar" was the title of a paper by Norman Nelson, Industrial Development Co. He described the operation of the Columbia Hardboard Plant in Everett, Wash., and a similar plant in North Carolina. During the discussion it was indicated that redcedar was very desirable for use in particle board because it required less resin.

At a general interest session, G. A. Atherton, Oregon Forest Products Research Center, described a study to determine the veneer production from heated and unheated logs. Although final results were not available, Mr. Atherton said there appeared to be some increase in the dollar value of veneer from some heated logs. Drying time for 3/16 heated veneer was about one minute less than for unheated 3/16.

"Trofdek Structural System" was discussed by J. C. Hockridge, Laminated Structures, Ltd. The system is structural roofing and flooring that consists of Douglas-fir lumber flanges spaced and held by sloping pieces of plywood.

Some of the anatomical differences among species that affect their pulping characteristics were discussed by C. E. Murray of Rayonier, Inc., in a talk entitled "Some Wood and Fiber Characteristics which affect Pulp Properties".

Strength differences that arise from variation in the pressing cycle for particle board were the subject of a paper by M. D. Strickler, Washington State Institute of Technology, entitled "Effect of Press Cycles and Moisture Content on Flake Board Properties".

The final paper of the meeting was presented by Mrs. Barry, Reichhold Chemicals, Inc. On "Gas Chromatography in the study of Formaldehyde Release in the Manufacture of Particle Board", the paper described a method for determining the amount of free formaldehyde.

Other features of the meeting were tours of the plant of British Columbia Mfg. Co. Ltd., and the new Vancouver Laboratory of the Forest Products Laboratories of Canada.

Ripley Elected Chairman of Pacific Southwest Section

New officers and trustees were elected at the Pacific Southwest Section meeting, Dec. 9, 1958, at Los Angeles, Calif., Secretary Anderson reported.

W. E. Ripley, Jr., Stauffer Chemical Co., was elected chairman; J. H. Miller, Reichhold Chemicals Inc., vice-chairman; and Ole Anderson, Weber Showcase & Fixture Co., secretary-treasurer. Elected trustee for one year was J. Richardson, California Furniture Shops. Fred Card, Allied Veneer Co., was elected trustee for two years.

The meeting program included a discussion on high pressure laminates by George Eberhart, U. S. Plywood Corp. A new color film, "The New Paul Bunyan" was shown by Mr. Walter Remak, Weyerhaeuser Sales Co.

DIVISION Views and News

Committee Chairman Chosen In Lumber Mfg. Division

Don MacRae, Connor Land & Lumber Co., has been appointed chairman of the Subcommittee on "Log Breakdown in the Sawmill" of the Lumber Manufacturing Division, M. H. Mater, Division chairman announced recently.

Duties of the sub-committee are to co-ordinate research on breaking down a log into lumber by various methods and machines. Subcommittee members will be chosen from different species regions of the United States and Canada.

Members of the committee so far are: Hereford Garland, Mich. College of Mining & Technology; Lionel Pease, Mill Equipment, Inc.; W. R. Warner, Southern Lumber Co.; and W. K. Stametz, Jr., The Enterprise Co.

Wood Machining Division Moves Ahead on 2 Projects

Progress is being made on the work of two subcommittees of the Wood Machining Division established at the 1958 National Meeting, N. C. Bye, Division chairman, reports.

The subcommittee on "Nomenclature Standardization for Wood Machining Tools" will be headed by James Lubkin, American Machine & Foundry Co. Recommendations on the scope and frequency of publication of the work of the subcommittee on "Annual Summary of New Wood Machining Literature is being prepared.

At the last National Meeting it was suggested that the latter committee prepare an annual summary of significant new wood machining literature that will include title, author, documentation, short explanation of text, and how further details can be obtained.

March Logging Conference to be held in Redwood Region

The 21st annual Redwood Logging Conference will be held March 12–13, 1959, at Santa Rosa, Calif., W. E. Baker, president of the association announced recently. Headquarters will be the Flamingo Hotel.

Discussions will center on log loading machinery, tractor operation and maintenance, felling and bucking problems, salvage logging methods and markets, and legal problems. The program will include several panels including loggers and equipment dealers.

Rules and Judges Announced For 1959 Wood Award Contest

The 10th Annual Wood Award Competition will again be held in 1959, James S. Bethel, Chairman of FPRS Industry–Education Division, and J. F. Koellisch, editor of WOOD AND WOOD PRODUCTS magazine announced recently.

Judges chosen for the 1959 Wood Award by Dr. Bethel are: Dr. S. B. Preston, University of Michigan, chairman of the committee; Dr. Fred Brown, Dow Chemical Co., Midland, Mich.; and Dr. Robert L. Youngs, USFPL.

Purpose of the Competition

Designed to encourage research in wood technology, the competition attracted 13 entries in 1958, the largest number since the awards were begun. Because of the consistently high caliber of the entries last year, three honorable mentions were chosen in addition to the first and second place winners.

Qualifications for Entry

The competition is open to persons who were or are in attendance as graduate students for at least one quarter or semester at any North American university or college between January 1, 1958, and April 30, 1959. Two cash awards and certificates are presented by WOOD AND WOOD PRODUCTS magazine in cooperation with FPRS.

The first place winner will receive $350, and second place, $150, with the awards to be presented at the 13th National Meeting of the Forest Products Research Society, June 28–July 3, 1959 at San Francisco. The winner of the first award will be invited to present his paper at one of the meeting's technical sessions.

Entry Dates

Deadline for submission of tentative titles is April 1, 1959. The complete paper, in triplicate, must be submitted by May 1, 1959, to the FPRS Executive Secretary, 417 North Walnut Street, Madison, Wisconsin.

The 1958 first-place winner was Howard Spalt, who received the award for his paper on "The Fundamentals of Water Vapor Sorption by Wood". "Strength Retention in Wood Decayed to Small Weight Losses" was the title of the second ranking paper by R. W. Kennedy.

The competition was begun in 1948, and the first recipient of the award was N. V. Poletika, now director of research and development, Union Lumber Co. Poletika's paper was entitled "A New Method for Studying the Elastic Behavior of Wood". Prior to his present position, Poletika was director of research for the Timber Engineering Co. The distinction achieved by many of the early Wood Award winners reflects the high level of the competition.

BUSINESS TRENDS

Lumber—1959 Outlook

The industry expects an increase of about 3.5% in production, 6.6% in gross sales, and 3.8% in lumber consumption. The most important factor that could influence the lumber industry favorably is the prospect of residential construction sustained at a level of 1,200,000 or more units.

Other factors are the anticipated increase in production in the pallet industry, a better year for the furniture industry, and requirements for highway construction of about 468 million bd. ft., or 10% more than in 1958. Railway ties equivalent to 880 million bd. ft. may be laid in 1959, compared to 745 million bd. ft. in 1958.

The use of wood waste for particle board, pulp chips, and so on, will provide an additional source of revenue for the lumber industry. The use of lumber for wooden boxes and crates is not expected to exceed 1958, however, and may decline if the trend toward packing fruits and vegetables in paper cartons continues.

Lumber—Summary of 1958

Lumber production in 1958 is estimated at about 32 billion bd. ft., 3% below that in 1957. Production during the first 9 months was approximately 5% below the comparable period of 1957. Accelerated construction activity in 1958 was reflected in a higher rate of lumber output, but did not provide sufficient stimulus soon enough to permit total lumber production to rise to the 1957 level.

Softwood Plywood—1959 Outlook

The industry is expected to establish its 13th consecutive production record in 1959, with an output in excess of 6,500 million sq. ft., 3/8 in. basis, an estimated increase of 10% over 1958. Promotional activity will be aimed at diversification in market outlets and will attempt to increase the percentage of softwood plywood used in home, school, farm, and railroad car construction. A better national economic climate is expected to eliminate recurring price valleys.

Softwood Plywood—1958 Summary

Production through the third quarter of 1958 was 11.4% above the corresponding period of 1957. Even though a production cutback of 20 to 25% was made in the fourth quarter, the industry is expected to establish its 12th consecutive production record, estimated in excess of 6,000 million sq. ft., 3/8 in. basis. Production in 1957 was 5,653 million sq. ft.

Hardwood Plywood—1959 Outlook

The possibility of an upward revision to 750 million sq. ft., in the Japanese voluntary hardwood plywood export quota, and the pronounced trend toward lower prices of many other countries exporting to the United States, forecast an unfavorable outlook in 1959 for the domestic market hardwood plywood industry.

Hardwood Plywood—1958 Summary

Shipments are estimated at about 760 million sq. ft., surface measure, compared with 793 million in 1957. The decline in domestic shipments occurred despite the increase in domestic consumption, which amounted to an estimated 1,602 million sq. ft. surface measure in 1958.

Hardwood plywood imports have climbed steadily from 619 million sq. ft., surface measure, in 1955, to 842 million in 1958. Imports were in excess of domestic shipments in 1958 by 10.8%. Japan provided most of the hardwood plywood imports, an estimated 660 million in 1958 (78.5%). Countries such as Canada, Finland, and Sweden, with traditional plywood export markets in the United States, have reduced their prices to the Japanese level, thereby adding to the competitive situation in the United States market.

Particle Board

A recently completed survey by the Business and Defense Services Administration shows 46 particle board manufacturers in operation in 19 states. Production for 1957 was 182,884,000 sq. ft. This included 144,451,000 sq. ft. of platen-type board from 28 manufacturers, and 38,443,000 sq. ft. of extruded board from 18 manufacturers.

Foreign output is ahead of domestic figures. Particle board is now being produced in the Union of South Africa, Latin America, Far East, Near East, and Oceania. Europe, however, has witnessed the greatest increase in production.

Forest Products Division
Business and Defense Services Administration
U. S. Department of Commerce

Beech Utilization Discussed At November Northeast Meeting

The culmination of 12-year research project by the Northwestern Technical Committee was a conference on "Better Utilization of Northeastern Beech", held Nov. 6–7, at Montpelier, Vermont. Attended by 75 loggers, lumbermen, wood processors, and researchers, the meeting was sponsored by the Northeastern Loggers' Assoc. and the Vermont Bureau of Industrial Research.

During the 12-year period, the Committee has prepared 17 papers on aspects of beech utilization, which have been published and distributed. Four additional papers will complete the series. F. C. Simmons, Northeastern For. Exp. Sta., opened the meeting with a short history of the project.

Banquet speaker N. Nash, Sales Mgr., Great Eastern Lumber Co., talked on "Cultivating Markets for Beech Lumber". Paul Graham, Clinic of Wood, in his paper on "Beech for Turning and For Furniture" stated, ". . . beech is an ideal furniture wood . . . of sufficient merit to be presented . . . under its own identity, rather than to masquerade as woods it supplements. . ." Registrants agreed that an intensive publicity campaign extolling the virtues of Northeastern Beech should be undertaken by interested agencies.

Resources Reviewed

More than half of the standing beech in the country is located in the twelve Northeastern States, Elliot Amidon, Northeastern Forest Exp. Sta., pointed out. The area contains more than 12 billion board feet of standing beech saw-timber of which 30 per cent is Grade I or Grade II factory lumber logs. Only about 30 per cent of the net growth of beech in the Northeast is being cut for use, he said.

Less than one-third of potential high-quality beech content in trees cut today goes into high-quality uses, F. C. Simmons stated. Part of this failure, he said, is because beech ends up in uses that would be satisfied with lower quality material. The greater part he attributed to degrade because of stain, decay, checking, mistakes in sawing and bucking practices, and losses from mechanical injuries and miscuts.

Other topics covered at the meeting were: air and kiln drying of beech; use of beech for pallets, containers, flooring, railroad ties, structural use, rough construction on the farm, veneer and plywood and pulp.

Graduate Sessions in Statistics Offered at N. C. State College

The 1959 Southern Regional Graduate Summer Session in Statistics will be held at North Carolina State College, Raleigh, from June 9 to July 17, 1959. Cooperating institutions are Virginia Polytechnic Institute, University of Florida, and Oklahoma State University.

The six week session is intended to serve teachers, research workers, statisticians, and graduate students in statistics and other fields that require work in statistics.

The National Science Foundation is offering 30 grants to college teachers of introductory statistics who wish to attend the session. Applications for grants must be received not later than Feb. 16, 1959. Information about the grants and applications for enrollment are available from F. E. McVay, Dept. of Experimental Statistics, N. C. State College, Raleigh.

Control of Bacterial Attacks On Mill Ponds Now Studied At U of California Laboratory

Two methods that show promise of controlling bacterial attacks in millponds are being studied at the University of California Forest Products Laboratory, it was reported recently.

The bacterial attacks are thought to create a porous condition in ponderosa and sugar pine, which causes an excessive absorption of the toxic water-repellent solution during dip treatment for millwork. Further complications are encountered when the solvent-soaked wood is painted.

After some 121 different tests involving 22 bactericides and other chemicals, two methods that may be successful were found by researchers, Eric Ellwood and Barton Ecklund of the Laboratory. One method would employ an acid and the other a common salt. Earlier work on this problem was performed by Dr. A. W. Stout, Western Pine Assoc.

Two Industrial Forestry Seminars Announced by Yale

Dates for the 10th and 11th sessions of the Yale Industrial Forestry Seminars have been announced recently by Z. W. White, Prof. of Industrial Forestry at Yale University.

The 10th session will be held March 2–13, at Crossett, Arkansas, in cooperation with The Crossett Co., and the 11th April 6–17, at New Haven, Conn.

"FPRS Salutes"

Men Contributing Time and Effort for Furtherance of the Society and Wood Industry

R. H BERRY

Raymond H. Berry—as General Chairman of the 1959 National Meeting is chief administrator in the organization of the many phases necessary for a successful meeting. Coordinating the efforts of his committee is one of his major responsibilities. Currently FPRS vice president, he brings an unusual combination of training and experience to the assignment. Mr. Berry received his LL.B at Yale University Law School and practiced law for 13 years in New Jersey. Before receiving his degree from Yale, he studied at the Sorbonne.

Since 1938 he has been with the Scott Lumber Co., Burney, Calif., and is now vice president, secretary, and general manager of the firm. He is also a director of the Western Pine Assoc. and an alternate director of NLMA. He has been chairman of the FPRS Executive Building Fund and served as a regional board member.

F. E. DICKINSON

Fred E. Dickinson—in charge of publicity for the '59 National Meeting, is himself a prolific writer. With more than three dozen titles to his credit, he has served as a reviewer for the JOURNAL. As publicity chairman he is responsible for supplying the trade press and local newspapers with advance information. Dr. Dickinson is former chairman of the Northeastern Section and was also general chairman of the 1954 National Meeting. He is currently Southwest Regional Board member.

Dickinson is director of the Forest Products Laboratory and professor of forestry at the University of California, Richmond. He earned degrees at Minnesota, Michigan State, and received his doctorate degree in wood utilization from Yale University. He has worked for the University of Michigan, Yale, the War Dept. and the USFPL.

N. T SHELTON

N. Thomas Shelton—will be arranging plant tours that should be of interest to 1959 National Meeting registrants. Long associated with FPRS, Mr. Shelton is a past chairman of the Northern California Section. He has written articles that have appeared in the JOURNAL and other technical magazines.

An industrial engineer, he received his degree in mechanical engineering at Cornell University. He is currently chief industrial engineer for the Diamond Gardner Corp., with whom he has been associated for the past 12 years. He was previously associated with industrial management firms and Hughes Aircraft. Mr. Shelton is a member of ASME and the California Water Pollution Control Board.

Kiln Drying Demonstration Planned in April at USFFL

The 83rd Kiln Drying Demonstration, designed to make research findings and operational practices easily available, will be held April 13–24, at the U. S. Forest Products Laboratory, Madison, Director J. A. Hall announced recently.

Subjects to be covered include principles of air and kiln drying, types of kilns, kiln equipment, drying schedules, operation and tuneup of kilns, and moisture control during storage and production. In addition, enrollees will dry charges of lumber in Laboratory kilns and work practical problems in the use of moisture meters, balances, and other instruments.

Time will be allowed for participants to discuss individual problems with Laboratory staff. Cooperative fee for the 2-week demonstration is $250 per man, and includes materials and publications. Each firm may enroll as many representatives as it wishes.

NAMES in the NEWS

J. V. Williams has recently been appointed West Coast representative for the Hardwood Corp. of America, W. C. Anderson, general manager of the firm, announced recently. Mr. Williams was previously associated with E. J. Stanton & Son and the Angelus Hardwood Co.

Appointed sales manager of the North Central region of the Drake Corp. is **Louis Painter**, the firm announced recently.

Dr. James S. Bethel has been granted a one year's leave of absence from N. C. State College to serve with the National Science Foundation, it was announced recently. Dr. Bethel starts his new duties Jan. 1959.

Business . . .
Changes, Mergers, Expansion

Construction of a new **Borden Chemical Co.** coatings and adhesives manufacturing plant has been started at Illiopolis, Ill., it was announced recently. The half-million dollar plant is expected to be in production by July 1, 1959, and is designed to serve the Midwestern packaging, building, coatings, and adhesives industries.

Dorr-Oliver Inc. announced recently the appointment of Wilco Machine Works, Inc., Memphis, Tenn., as its exclusive representative in the United States for marketing D-O designed flakeboard production plants. This development arose out of the D-O expansion of its activities in 1958 into the hardboard, particle board, and wallboard fields.

The **G. M. Diehl Machine Works, Inc.**, Wabash, Ind., has purchased the firm of I. H. Bradley & Son, both firms announced recently. All engineering and manufacturing will be moved to Wabash, Ind., with products marketed under the name "Diehl-Bradley".

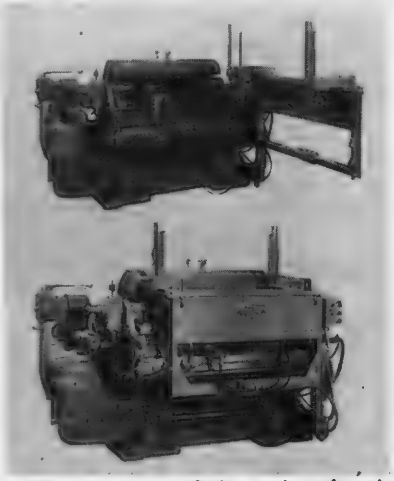
Greenlee Bros. & Co., Rockford, Ill., recently acquired the Buss Machine Work, Holland, Mich., and their subsidiary B. & T. Machinery Co. L. H. Geddes, Exec. Vice-Pres. and Treas. of Greenlee stated recently that present plans are to retain Buss personnel, and sales of Buss machinery will continue through the Buss dealer organization. The Buss line of machinery will continue to be competitive with the Greenlee line.

NEW PRODUCTS *and Literature*

Lathe for Turnings 42" Long

An automatic shaping lathe for turnings up to 42 inches long is now being produced by Mattison Machine Works. The "No. 69" automatic shaping lathe has an air-operated steadyrest and electrically-operated hopper feeding attachment.

The hopper feeding attachment is hinged and can be swung outward without disturbing set-up adjustments. The machine will handle stock from a minimum of ¾ inch square to a maximum of 4 inches square and up to 42 inches long. It has an air-operated carriage, air-operated tail stock, and hopper feed.



The diameter of the main arbor is 2⅝ inches and main arbor speed is 2700 rpm. It has a 15 hp main drive motor, and the feed motor, 2-speed, reversing, is 1½ hp. Rates of feed are 2, 3, 4, 6, 10, 15, 20, and 30 rpm. More information is available from the Mattison Machine Works, Rockford, Ill.

Automatic Fabricating Machine

A high-speed, automatic fabricating machine designed to cut, notch, and groove TECO trussed rafters has been developed by the Ruvo Engineering Co., engineering affiliate of NLMA.

Production capacity for this fabricating line, a system of saws, drills, and pneumatically controlled clamps, is based on the production requirements of the builder or roof-truss fabricator.

Drills and saws can be moved in any position along the entire length of the line to handle material of varying lengths. Saws can be swung to any angle to accommodate truss designs of different slopes through push button control. Further information is available through Timber Engineering Co., 1319 18th Street, N. W., Washington 6, D. C.

(See page 29-A for Continuation of News-Digest)

EMPLOYMENT *Opportunities*

The FPRS Employment Service is operated without charge as a service to members. Companies or institutions with positions to be filled or individuals seeking employment may participate in this program by inserting a free ad in two consecutive issues of the FOREST PRODUCTS JOURNAL. Inquiries concerning employment listings or ads to be placed in the JOURNAL should be addressed to FPRS Employment Service, P. O. Box 2010, University Station, Madison 5, Wis. Correspondence is kept confidential.

Employment Wanted

No. 503—Quality control position desired by wood utilization major. Three summers experience with Forest Service. Was student trainee at USFPL. Experience in paint research laboratory. Desires Midwest or Northwest. Available March. (Feb.)

No. 517—Position desired with American logging co. in tropics. Has 10 years experience with timber industry as area manager on timber extraction. Extensive knowledge of both hand and mechanical logging methods in Africa and Malaya. Has forestry education. Speaks Malay. Available for interview in United States or Canada. (Feb.)

No. 518—Position desired in sales, sales management, or management in wood products industry or associated chemical industries. Four years sales experience and M.S. in Forestry with wood products marketing option. (Feb.)

No. 520—Position desired with lumber company, pulp and paper company, or university, in the field of research, public relations, or teaching. Received M.S. in 1958. Has done summer work in various fields of forestry. Experienced as reporter-photographer for three years. (Feb.)

WANTED

Moulder set-up man for mouiding plant in Wisconsin. Give complete details of experience, personal data and salary expected.

CECRAFT MANUFACTURING COMPANY, INC.
418 East South Street
STOUGHTON, WISCONSIN

FPRS FOREST PRODUCTS JOURNAL
VOL. IX, NO. 1
JANUARY, 1959

Preservative Moisture-Repellent Treatments *for* Wooden Packing Boxes

A. F. VERRALL[3]

Southern Forest Experiment Station,
U. S. Department of Agriculture,
New Orleans, La.

Three-minute dips protected boxes for a short time against wetting and 3 to 5 years against decay; soil poisons were needed to stop termites. Pressure treatments protected against both.

Fig. 1.—Test exposure piles. (Cover) Fully exposed pile of M22 boxes on poisoned soil, Mississippi. (Above) M22 boxes exposed in jungle, Panama.

THE WOODS COMMONLY USED for shipping crates and boxes have no appreciable natural resistance to fungi and insects. Consequently, containers exposed to the elements are usually attacked by biological deteriorating agents. These agents include decay fungi that destroy wood, and staining and molding fungi that cause little loss in strength but can obscure stencil markings.

For fungus decay it is necessary, of course, for the wood to be wet (above 20 per cent moisture content) but not water-soaked, and for temperatures to be between 50 and 100° F. Termites do not require wet wood for attack, but merely an unobstructed passage from their nest to the wood.

Military Exposures May Be Severe

Wooden boxes and crates for most civilian use are seldom fully exposed long enough to suffer serious fungus decay. Even for military use during peace-time, containers are stored mostly in buildings and consequently are not seriously attacked. In war, however, it is often necessary to store large amounts of ammunition, supplies, and equipment in containers fully exposed to the elements. Heavy fungus deterioration of wooden containers so stored occurred in the South Pacific and continental United States during and just after World War II; often, wooden ammunition boxes were rendered useless after one year. Before ammunition igloos were sufficiently ventilated and waterproofed, wooden boxes stored in them decayed rapidly in both the southern and northern states.

The heartwood of some tree species is naturally decay-resistant, but high costs and limited supplies preclude its general use in box manufacture. A number of common preservatives, when impregnated into wood, will give longtime protection, but usually there is doubt that enough units of a given type of container will be exposed to an extent that would warrant the general use of pressure treatments. Also, poor paintability of wood pressure-treated with some oils and the need for reseasoning boxes impregnated with water solutions would be factors against the use of some pressure treatments.

Dip Treatments

A 3-minute dip or a vacuum treatment with light petroleum solutions of such preservatives as pentachlorophenol has been widely used in the sash and door industry for a number of years. There is little exact data on the protection afforded, but the general impression is favorable. During the past 15 years, considerable experimental evidence has been accumulated on the effectiveness of surface applications of preservatives by brushing, dipping, or soaking for short periods. In soil-burial tests, surface applications ex-

[1] This study was conducted in cooperation with Pitman-Dunn Laboratories, Frankford Arsenal, Army Ordnance Corps. The tropical exposure site was furnished by the Naval Research Laboratory, U. S. Navy.

[2] A short summary of this report was presented at Session V, Wood Preservation, FPRS 12th National Meeting, held June 22–27, 1958, in Madison, Wis.

[3] Aid in planning, executing, and interpreting these studies was given by L. Teitell, Pitman-Dunn Laboratories and by R. M. Lindgren and T. C. Scheffer, U. S. Forest Products Laboratory.

The Author: Arthur Verrall holds MS and PhD degrees from the University of Minnesota. A pathologist, he has authored numerous papers on fungus deterioration of wood and its control.

Fig. 1c.—Pile of M22 boxes covered with a tarpaulin, Mississippi.

Fig. 1d.—Simulated boxes exposed on creosoted sills, Mississippi.

tended service life only a little (1),[4] but in southern Mississippi (6) 3-minute dips materially increased the life of steps, porch floors, and step rails; 15-minute or longer soaks gave longtime protection to wood that was off the ground but still exposed to rain seepage. The data were sufficiently promising to warrent large-scale tests on the effectiveness of dips and short-period soaks in preventing deterioration of ammunition boxes.

MATERIALS AND METHODS

Test Units

The main test units, including all exposed in Panama and Wisconsin, were 3,000 M22 small-arms ammunition shipping boxes (cover) secured from new warehouse stock at Frankford Arsenal. At the time of treatment, the boxes were thoroughly dry, that is, at about 12 per cent moisture content, and relatively free of fungus stains, molds, and decay. Most wood in the boxes was eastern white pine but some was aspen, yellow-poplar, northern spruce, balsam, and hard pine. The boxes were kept in dry, indoor storage until they were treated, except for some in which moisture content at the time of treatment was under test.

At Gulfport, Mississippi, a number of supplementary tests were made with "simulated box" test units (Fig. 1D). These consisted of two pieces of nominal 1 by 8 lumber, 12 inches long, nailed to peripheral cleats about 1.5 inches wide. A 3/8-inch hole was bored in each face board to allow ready entry of water. In effect, the unit was a box with an interior void nominally 1 by 5 by 9 inches. These units permitted better matching of wood among test categories than did the more variable boxes. All the wood in these simulated boxes was free of obvious fungus infections, but in some tests wood was conditioned to various moisture contents or infected with fungi prior to treatment. Most of these boxes were made of the sapwood of southern yellow pine, but several other species were included.

Forty-eight M22 boxes were made at Gulfport from southern yellow pine sapwood, and divided into 4 groups: Untreated; dipped for 3 minutes in 5 per cent pentachlorophenol; dipped for 3 minutes in 5 per cent pentacholophenol plus a water repellent; and dipped for 3 minutes in 0.3 per cent copper 8-quinolinolate. No hardware was used on these boxes. Southern yellow pine was included because it is used in many types of ammunition boxes, is absorptive, and has low decay resistance.

One hundred wire-bound crates, largely of rotary-cut veneer of southern hardwoods, were dip-treated for exposure at Gulfport.

Treating Solutions

Following is a list of the fungicides and insecticides, solvents, and water repellents that were used.

Toxicants: *Borax.* Technical grade, finely granulated; used to fortify some water solutions.

Benzene hexachloride. Lindex WE–125, a concentrate containing 12.5 per cent gamma isomer.

Copper ammonium fluoride. A complex containing 5.1 per cent metallic copper, dissolved in water; concentration as per cent of the complex.

Copper 3-phenyl salicylate. Crystals dissolved in butanol (15 per cent) and aromatic mineral spirits (85 per cent).

Copper 8-quinolinolate. Cunilate 2174, a 10 per cent concentrate diluted with aliphatic mineral spirits.

Copper naphthenate. Nuodex Cu–8, a concentrate containing 8 per cent metallic copper diluted with aliphatic mineral spirits.

Copper pentachlorophenate. Technical grade crystals dissolved in methyl cellosolve (20 per cent) and diluted with aliphatic mineral spirits (80 per cent).

Orthophenylphenol. Crystals (Dowicide 1) dissolved in aliphatic mineral spirits. Concentrations expressed as per cent Dowicide 1. In cold weather, solubility was increased by using a small amount of aromatic mineral spirits.

Pentachlorophenol. Crystals (Dowicide 7) dissolved in aromatic mineral spririts and diluted with an equal amount of aliphatic mineral spirits (Concentrations expressed as per cent Dowicide 7); 8 per cent Hecolyn (methyl ester of hydrogenated rosin) was added to prevent blooming.

Phenyl mercuric oleate. IN–2555, a 10 per cent concentrate diluted with aliphatic mineral spirits.

Rosin amine D acetate. A 30 per cent concentrate diluted with water.

Rosin amine D pentachlorophenate. Technical grade, dissolved in aliphatic mineral spirits.

Sodium pentachlorophenate. Concentrations expressed as per cent Dowicide G in water.

Sodium tetrachlorophenate. Concentrations expressed as per cent Dowicide F in water.

Tetrachlorophenol. Concentrations expressed as per cent Dowicide 6; dissolved in aliphatic mineral spirits.

Zinc naphthenate. Nuodex Zn–8, a concentrate containing 8 per cent metallic zinc diluted with aliphatic mineral spirits.

Supplementary tests included several of the most widely-used commercial solutions of chlorinated phenols, and some water-borne salts were used for pressure treatment of some M22 boxes as listed under "Treatment."

Solvents: *Aliphatic mineral spirits.* Kyso, sold by Standard Oil Company of Kentucky.

Aromatic mineral spirits. SS–91, a petroleum mineral spirits with high aromatic content, sold by Southern Solvents, New Orleans.

[4] Numbers in parentheses refer to the Literature Cited at the end of this report.

Butanol. Sold by Commercial Solvents Corporation.

Methyl cellosolve. Sold by Carbide and Carbon Chemicals Company.

Water Repellents: Two of the proprietary products already contained water repellents. In most oil solutions, the water repellent consisted of 8 per cent Hercolyn (methyl ester of hydrogenated rosin) and 2 per cent paraffin wax (AMP 125° F.). The repellent for water solutions was 4 per cent paraffin wax added as 8 per cent Ceremul A, a 50 per cent wax emulsion sold by Socony Vacuum Oil Co. A few other repellents were tried in one or two tests and will be described later.

Concentrations: The concentrations and combinations of chemicals in the main test are given in Table 1. In general, the chemicals were used at three concentrations:

1) That ordinarily used for wood preservation or, for new chemicals, that which, from other uses and known properties, appeared to be suitable.

2) One-half the concentration used in 1), in the hope that quicker determination of the relative effectiveness of different chemicals might be secured; and

3) Twice the concentration used in 1), because it was thought that higher than usual concentration might be needed to protect boxes under the severe conditions in large piles exposed outdoors.

Treating

The M22 boxes were treated between April and July 1952. For dip treating, the box covers were wedged open ½ inch. For the main test, the treating procedure was: 1) weigh boxes, 2) dip for 3 minutes, 3) drain for 4 minutes, 4) reweigh, 5) open-pile under cover for 3 to 5 days for evaporation of solvent, and 6) solid-pile until exposed in the field. The 3-minute immersion period was chosen because it is commonly used in the sash and door industry; much of the absorption in short-period soaks occurs during the first minute, and a 3-minute dip can be fitted into production-line methods. For one supplementary test, immersions were for 5 and 10 seconds, and 1, 2, 3, and 10 minutes, in six different solutions.

To determine the effect of paint on protection and the effect of the main treatments on paintability and paint durability, some boxes were given 2 spray coats inside and outside with enamel (TT-E-485b, Type II, olive drab). Painting was delayed for at least 7 days after treatment to permit evaporation of the solvents.

The Forest Products Laboratory, Madison, Wisconsin, pressure-treated 221 boxes, primarily as reference ma-

Table 1.—AVERAGE RETENTIONS OF PRESERVATIVE, IN POUNDS OF SOLUTION PER CUBIC FOOT

Treatment	Panama		Mississippi						Wisconsin	
			With tarpaulin cover		Uncovered piles					
					Painted boxes		Unpainted boxes			
	WR	No WR	WR	No WR	WR	No WR	WR	No WR	WR	No WR
Oil Solutions, 3-Minute Dips										
Benzene hexachloride										
(0.5% gamma)	----	0.9	----	----	----	----	----	----	----	----
Copper naphthenate										
0.5% Cu	----	----	----	----	----	----	1.0	----	----	----
1.0% Cu	1.2	----	1.5	----	1.2	----	1.2	1.2	1.1	----
2.0% Cu	1.1	----	----	----	----	----	.9	1.1	----	----
Copper pentachlorophenate										
2.5%	----	----	----	----	----	----	1.4	----	----	----
5.0%	1.4	----	----	----	----	----	1.2	1.2	1.2	----
Copper 3-phenyl salicylate										
1.25%	----	----	----	----	----	----	1.2	----	----	----
2.5%	1.2	----	1.1	----	1.0	----	1.1	1.1	1.1	----
5.0%	1.1	----	----	----	----	----	1.2	1.1	----	----
Copper 8-quinolinolate										
0.15%	----	----	----	----	----	----	.9	----	----	----
0.3%	1.0	----	1.1	----	1.1	----	1.1	1.0	1.0	----
0.6%	1.0	----	----	----	----	----	1.2	1.0	----	----
0.3% plus 0.5% gamma benzene hexachloride	----	.9	----	----	----	----	----	.9	----	----
Mineral spirits										
(aliphatic) 100%	1.0	----	1.0	1.0	1.0	0.9	1.0	.9	1.0	----
Orthophenylphenol										
2.5%	----	----	----	----	----	----	.9	----	----	----
5.0%	1.2	----	1.1	----	1.0	----	1.1	1.0	1.1	----
10.0%	1.2	----	----	----	----	----	1.0	1.1	----	----
Pentachlorophenol										
2.5%	----	----	----	----	----	----	1.2	----	----	----
5.0%	1.1	----	1.1	----	1.1	----	1.1	1.2	1.1	----
10.0%	1.2	----	----	----	----	----	1.3	1.3	----	----
5.0% plus 0.5% gamma benzene hexachloride	----	1.2	----	----	----	----	----	1.1	----	----
Phenyl mercuric oleate										
0.15%	----	----	----	----	----	----	1.0	----	----	----
0.3%	.9	----	1.0	----	1.0	----	.9	.9	1.0	----
0.6%	1.0	----	----	----	----	----	.9	.9	----	----
Product containing 23% zinc naphthenate, 2.5% (coco) dodecyl-amine salt of tetrachlorophenol, and 28.5% water repellent										
25.0%	.9	----	----	----	----	----	1.0	----	----	----
37.5%	1.0	----	----	----	1.1	----	1.0	----	1.1	----
Rosin amine D pentachlorophenate										
2.75%	----	----	----	----	----	----	1.0	----	----	----
5.5%	1.0	----	1.1	----	.7	----	1.0	1.1	1.0	----
11.0%	1.0	----	----	----	----	----	1.0	1.0	----	----
Tetrachlorophenol										
2.5%	----	----	----	----	----	----	1.1	----	----	----
5.0%	1.0	----	----	----	----	----	1.0	1.1	1.0	----
10.0%	1.1	----	----	----	----	----	1.1	1.2	----	----
Zinc alkyl sulphonate										
2.8%	----	----	----	----	----	----	1.0	----	----	----
5.7%	1.1	----	----	----	1.1	----	1.0	----	1.2	----
Zinc naphthenate										
0.5% Zn	----	----	----	----	----	----	1.0	----	----	----
1.0% Zn	1.0	----	1.0	----	1.0	----	1.0	1.0	1.0	----
2.0% Zn	1.3	----	----	----	----	----	1.1	1.0	----	----
Water Solutions, 3-Minute Dips										
Copper ammonium fluoride										
5.0%	----	----	----	----	----	----	----	1.6	----	----
10.0%	1.6	1.6	----	1.6	----	1.7	1.3	1.6	----	1.7
20.0%	----	1.6	----	----	----	----	----	1.6	----	----
Product continaing sodium salts of dimethyl dithiocarbamic acid, 2-mercapto benzothiazole and pentachlorophenol										
2.5%	----	----	----	----	----	----	----	1.8	----	----
7.5%	----	2.1	----	----	----	----	----	2.1	----	----
Rosin amine D acetate										
2.5%	----	----	----	----	----	----	----	1.7	----	----
5.0%	----	1.9	----	----	----	1.7	----	1.7	----	1.9
10.0%	----	1.8	----	----	----	----	----	1.8	----	----
Sodium pentachlorophenate										
2.85%	----	----	----	----	----	----	----	1.8	----	----
5.7%	----	1.7	----	----	----	1.7	1.7	1.9	----	1.8
11.4%	----	1.8	----	----	----	----	----	1.7	----	----
2.0% plus borax 3.0%	1.6	1.8	----	1.8	----	1.8	1.6	1.9	----	1.7
4.0% plus borax 4.0%	----	1.8	----	----	----	----	----	2.0	----	----
Sodium tetrachlorophenate										
2.85%	----	----	----	----	----	----	1.7	----	----	----
5.7%	1.8	1.9	----	----	----	1.8	1.7	1.7	----	1.9
Water repellent										
4% solids	----	----	----	----	----	----	1.5	----	----	----
Oil Solution, Pressure Treatment										
Pentachlorophenol, 5%	5.8	5.6	----	----	----	5.2	5.5	5.8	----	5.2
Water Solutions, Pressure Treatments										
Copperized chromated zinc chloride	----	.81[1]	----	.80[1]	----	----	----	.70[1]	----	.78[1]
Tanalith	----	.34[1]	----	.37[1]	----	----	----	.29[1]	----	.34[1]
Celcure	----	.51[1]	----	.39[1]	----	----	----	.52[1]	----	.50[1]

[1] Expressed as pounds of dry salt.

Table 2.—RATE OF DECAY OF M-22 BOXES EXPOSED IN THE PANAMA CANAL ZONE

Treatment	Average decay rating[1]					Proportion of failure[2]				
	0.5 yr.	1.5 yr.	2.5 yr.	3.5 yr.	4.5 yr.	0.5 yr.	1.5 yr.	2.5 yr.	3.5 yr.	4.5 yr.
						Per cent				
Oil Solutions, 3-Minute Dips										
Benzene hexachloride (0.5% gamma)	2.3	2.6	4.1	4.9	---	0	0	58	100	---
Copper naphthenate										
1% Cu plus WR	.1	.4	1.3	2.4	3.6	0	0	0	23	35
2% Cu plus WR	.0	.0	.4	2.0	2.8	0	0	0	10	20
Copper pentachlorophenate										
5% plus WR	.2	.3	1.5	2.6	3.0	0	0	0	9	9
Copper 3-phenyl salicylate										
2.5% plus WR	.4	.5	2.0	3.8	4.5	0	0	10	50	75
5.0% plus WR	.0	.6	1.9	3.7	4.4	0	0	0	50	83
Copper 8-quinolinolate										
0.3% plus WR	.1	.7	2.3	3.9	4.4	0	0	17	57	77
0.6% plus WR	.1	.6	1.7	3.5	4.5	0	0	0	33	80
0.3% plus 0.5% gamma benzene hexachloride	.5	1.4	2.6	4.4	4.7	0	0	0	70	89
Orthophenylphenol										
5% plus WR	1.0	1.0	2.2	3.5	4.0	0	4	9	35	62
10% plus WR	1.0	1.3	1.9	4.0	4.4	0	0	0	50	78
Pentachlorophenol										
5% plus WR	.4	.4	1.9	2.9	3.6	0	0	5	25	25
10% plus WR	.2	.8	1.8	2.8	4.1	0	0	0	17	57
5% plus 0.5% gamma benzene hexachloride	.6	.9	2.0	3.1	3.7	0	0	0	18	36
Phenyl mercuric oleate										
0.3% plus WR	.1	.9	2.4	4.5	4.6	0	0	5	65	89
0.6% plus WR	.3	1.0	2.0	4.3	5.0	0	0	0	67	100
Product containing 23% zinc naphthenate, 2.5% (coco) dodecyl-amine salt of tetrachlorophenol, and 28.5% water repellent										
25% plus WR	.5	1.4	3.3	4.9	---	0	0	30	100	---
37.5% plus WR	1.1	1.3	3.4	4.9	4.9	0	0	30	90	100
Rosin amine D pentachlorophenate										
5.5% plus WR	.3	.3	1.9	2.9	3.6	0	0	0	18	33
11.0% plus WR	.2	.7	1.8	3.0	3.8	0	0	0	11	50
Tetrachlorophenol										
5% plus WR	.2	1.2	2.9	4.0	4.5	0	0	10	50	90
10% plus WR	.2	.5	1.5	2.5	3.2	0	0	0	9	9
Water repellent only	1.3	2.1	3.3	4.5	4.8	0	0	28	84	91
Zinc alkyl sulphonate										
5.7% plus WR	.6	1.2	2.8	4.6	5.0	0	0	30	70	100
Zinc naphthenate										
1% Zn plus WR	.3	.5	2.6	4.1	4.7	0	0	16	63	88
2% Zn plus WR	.6	1.1	2.3	3.9	4.2	0	0	20	56	78
Water Solutions, 3-Minute Dips										
Copper ammonium fluoride										
10%	.5	1.1	3.3	4.5	4.6	0	0	5	77	88
20%	.2	.6	2.4	4.4	5.0	0	0	0	78	100
10% plus WR	.5	.7	2.0	3.3	4.7	0	0	0	45	88
Product containing sodium salt of dimethyl dithiocarbamic acid and 2-mercapto benzothiazole and pentachlorophenol, 7.5%	.6	1.1	2.6	4.2	4.4	0	0	36	73	78
Rosin amine D acetate										
5%	.4	1.2	3.3	4.5	4.9	0	0	36	82	100
10%	.2	.7	1.3	3.3	4.2	0	0	0	36	56
Sodium pentachlorophenate										
5.7%	.4	.5	2.0	2.9	3.6	0	0	0	9	44
11.4%	.2	.6	1.9	3.0	3.5	0	0	0	9	40
2.0% plus borax, 3%	.5	.5	2.3	3.4	3.7	0	0	18	32	48
4.0% plus borax, 4%	.3	.6	1.7	2.7	3.4	0	0	0	9	22
2.0% plus borax, 3%, plus WR	.3	.7	2.4	3.8	4.3	0	0	10	50	70
Sodium tetrachlorophenate										
5.7%	.2	.6	2.4	3.6	3.8	0	0	0	30	56
5.7% plus WR	.7	.8	2.9	3.9	4.4	0	0	9	55	80
Oil Solutions, Pressure Treatments										
Pentachlorophenol										
5%	.2	.5	1.7	2.0	2.9	0	0	13	19	20
5% plus WR	.2	.4	.7	1.9	2.9	0	0	0	10	15
Water Solutions, Pressure Treatments										
Copperiazed chromated zinc chloride	.0	.1	.2	.7	2.4	0	0	0	0	0
Tanalith	.1	.3	1.3	3.1	3.2	0	0	0	13	13
Celcure	.1	.0	.4	1.6	2.8	0	0	0	11	19
Untreated	1.4	2.1	3.1	4.3	4.8	0	6	25	81	88

[1]Ratings on a basis of 0 (none) to 5 (destroyed).
[2]Percentage of boxes in decay classes 4 and 5.

terial in interpreting results with the dip treatments. Five common commercial solutions were used:

1) Five per cent pentachlorophenol plus 4 per cent Hercolyn in Enjay Solvent #3,

2) Five per cent pentachlorophenol plus 8 per cent Hercolyn and 2 per cent paraffin in Enjay Solvent #3,

3) Celcure (Federal Specification TT-W-546) 1.7 to 1.8 per cent in water,

4) Tanalith (Federal Specification TT-W-573) 0.9 to 1.2 per cent in water,

5) Copperized chromated zinc chloride (dry salts 73 per cent zinc chloride, 20 per cent sodium dichromate, and 7 per cent cupric chloride), 2.7 per cent in water.

The oil solutions were applied by the Rueping process and the water solutions by the full-cell method.

Exposure

The M22 boxes were exposed, starting in the summer and fall of 1952, at 3 geographical locations: Madison, Wisconsin (average rainfall 31 inches, 171-day growing season); Gulfport, Mississippi (average rainfall 60 inches, 276-day growing season); and Fort Sherman, Panama Canal Zone (average rainfall 130 inches, 365-day growing season).

1) At Madison, all boxes were put in three piles (4 by 6 by 4 boxes high) on untreated soil under the partial shade of hardwood trees.

2) At Gulfport, the main test was exposed as four piles under partial hardwood shade. Three piles were 7 by 16 by 4 boxes high (Fig. 1A). Two of these were on untreated soil from which leaf litter had been removed. The third was on soil that, after removal of leaf litter, was sprinkled with 5 per cent DDT in diesel oil at the rate of 1 pint per square foot. The DDT was for the exclusion of termites. The fourth pile, 6 by 6 by 6 boxes, was on similarly treated soil but was covered, while the boxes were dry, with a tarpaulin (Fig. 1C).

3) In Panama, three piles, 6 by 8 by 4 boxes high (Fig. 1B), were placed under jungle cover at the Naval Research Laboratory's Tropical Exposure Site, Fort Sherman. Two of these piles were on untreated soil while the third was on soil treated with 5 per cent DDT in No. 2 fuel oil at the rate of 0.8 quart per square foot. The soil was retreated after 6 months and the border was again retreated after 18 months.

Two other piles (4 by 6 by 4 boxes high) were on a concrete slab under partial shade at Fort Sherman. Cracks and breaks in the concrete within 5 feet of the piles were flooded with DDT in diesel oil. The boxes were placed on 10-oz. canvas that had been saturated with 5 per cent pentachlorophenol in oil, dried, and, after being placed on the concrete, saturated with 5 per cent DDT in diesel oil.

The simulated boxes were all exposed off the ground at Gulfport on specially constructed tables or sills made of treated wood (Fig. 1D). At first the units were solid-piled in tiers of five, but later the tiers were separated ¼ to ½ inch to remove border effects between good and poor treatments.

Fig. 2.—(Left) Black, wet rot. This rot, with a shell of softenedwood, was common in many of the treated boxes in Panama. (Right) Mycelial fan of water-conducting rotter (*Poria incrassata*) growing upside of a dry box under tarpaulin cover. This fungus can rot boxes without rain-wetting, but is rarely encountered.

Absorption of Preservatives

Because of the high variability of the wood among boxes, particularly the percentage of non-penetrable heartwood and the presence of some boards of species that treat with difficulty, or erratically, there were large variations in the absorption of preservatives. With the 3-minute dip the range for individual boxes was 0.2 to 3.3 lb. per cu. ft. for oil solutions and 0.5 to 2.5 lb. per cu. ft. for water solutions. Average absorptions are listed in Table 1. Average pounds of solution absorbed per cubic foot for all comparable treatments were:

	Water solutions	Oil solutions
Straight toxicant	1.8	1.1
Toxicant, plus water repellent	1.6	1.1

Absorptions were significantly greater for the water solutions than for the oil solutions. The addition of water repellents to the oil solutions did not reduce absorptions. In other tests, significant reductions have been reported (6, 8).

Absorptions for different immersion periods are listed in Tables 10 and 11. These data substantiate previous findings (2, 8) that, with dips and short-period soaks, most absorption occurs during the first minute or less.

A large variation in absorption among wood species and between sapwood and heartwood is shown in Table 8.

Previous tests had shown that absorptions and penetrations by dip treatment are reduced as wood moisture content increases (2, 8), and that moisture contents above fiber saturation (about 30 per cent) particularly hinder treatment. Similar effects were found in these tests (Table 12).

The average retentions by pressure-treated boxes are listed in Table 1. Retentions of individual boxes varied from 3.3 to 8.4 lbs. per cu. ft. for 5 per cent pentachlorophenol solution; 3.2 to 9.3 for 5 per cent pentachlorophenol plus water repellent; 0.267 to 0.479 (lb. salt) for Celcure; 0.218 to 0.479 (lb. salt) for Tanalith; and 0.432 to 1.115 (lb. salt) for copper-ized chromated zinc chloride.

The wire-bound cases of rotary-cut veneer absorbed the preservative solutions readily (Table 7). Further tests with rotary-cut sweetgum veneer (4 by 4-inch squares of kiln-dried ¼-inch veneer) showed the following absorptions (pounds of copper naphthenate solution per cubic foot) with various immersion periods:

	1 sec.	2.5 sec.	5 sec.	10 sec.	1 min.	3 min.
Sapwood	5.8	6.4	7.7	8.6	9.9	9.7
Heartwood	4.5	4.4	4.6	6.0	5.6	5.8

These excessive absorptions by veneer are possibly due to three factors: The relatively large ratio of surface to volume would increase absorption per unit of volume; when rotary-cut veneer is flattened, a multitude of fine checks develop on the formerly concave surface; rapid kiln drying permanently increases absorptiveness (5). In these tests, lateral penetration of the solution into veneer was often complete, whereas sweetgum lumber showed practically no lateral penetration.

Fungus Attack

In both Gulfport and Panama, a number of molds occurred on boxes. These included *Pestalozzia* associated with a white molding, *Aspergillus niger* on copper treatments, *Penicillium, Trichoderma, Tubercularia,* and *Gliocladium.* However, molding and staining sufficiently severe to obliterate stencil markings occurred only on untreated boxes or those given treatments that were ineffective against decay. Molds and stain therefore will not be given further attention in this report.

The most common decay fungi on rain-wetted wood at Gulfport were *Lenzites saepiaria* and *Daedalea berkeleyii* on coniferous woods and *Polyporus versicolor* on hardwoods. Where in contact with soil, coniferous woods were commonly attacked by *Poria radiculosa* and in one pile by the water-conductor *Poria incrassata* (Fig. 2). The latter, unlike most decay fungi, has the ability to wet dry wood ahead of its advance, but fortunately it is of rare occurrence. Thus brown rot predominated on coniferous woods in the Mississippi exposures.

The only identified Basidiomycete that caused decay in Panama was *Odontia bicolor,* which was prevalent among isolations made in 1954 and 1955. In addition, an unidentified decayer with light tan mycelium was particularly destructive in a covered pile that was comparatively dry. A black wet-rot (Fig. 2) was also common in Panama on wood too wet for rapid decay by most wood-destroying Basidiomycetes. An imperfect fungus, *Diplodia natalensis,* was isolated from black wet-rot. In many cases a thin shell of softened wood developed similar to the slow decay caused in saturated wood of cooling towers by such Ascomycetes as *Chaetomium.*

In Wisconsin, the principal type of decay was white rot. No causal fungi were identified.

At none of the test sites was there an apparent difference in species of decay fungi on treated and untreated boxes.

Decay ratings were based on an arbitrary scale of 0 to 5 as follows:

Rating	Decay Class
0	None
1	Suspicious only
2	Small spots only
3	General, but little loss in strength
4	Heavy decay, serious loss in strength
5	Practically destroyed

Table 3.—RATE OF DECAY OF M–22 BOXES EXPOSED WITHOUT TARPAULIN COVER IN SOUTHERN MISSISSIPPI

Treatment	Average decay rating[1]										Proportion of failure[2]									
	With water repellent					Without water repellent					With water repellent					Without water repellent				
	1.2 yr.	2.2 yr.	3.2 yr.	4.2 yr.	5.1 yr.	1.2 yr.	2.2 yr.	3.2 yr.	4.2 yr.	5.1 yr.	1.2 yr.	2.2 yr.	3.2 yr.	4.2 yr.	5.1 yr.	1.2 yr.	2.2 yr.	3.2 yr.	4.2 yr.	5.1 yr.
											Per cent									
Oil Solutions, 3-Minute Dips																				
Copper naphthenate																				
0.5% Cu	0.5	0.6	0.8	1.5	2.1	---	---	---	---	---	0	0	0	0	8	---	---	---	---	---
1.0% Cu	.2	.4	.5	1.0	2.1	0.0	0.2	0.3	1.0	1.6	0	0	0	8	17	0	0	0	0	8
2.0% Cu	.0	.3	.3	.8	1.1	.2	.2	.3	.8	1.0	0	0	0	0	0	0	0	0	0	0
Copper pentachlorophenate																				
2.5%	.0	.0	.3	1.4	1.9	---	---	---	---	---	0	0	0	0	8	---	---	---	---	---
5.0%	.2	.2	.2	.8	1.9	.2	.3	.3	.6	1.7	0	0	0	0	8	0	0	0	0	0
Copper 8-phenyl salicylate																				
1.25%	.3	.5	.8	2.0	2.8	---	---	---	---	---	0	0	0	8	17	---	---	---	---	---
2.5%	.2	.5	1.1	2.5	3.3	.3	.9	1.8	2.5	3.0	0	0	0	8	42	0	8	17	25	42
5.0%	.2	.7	1.4	2.2	3.1	.2	.3	1.0	2.2	2.7	0	0	0	8	33	0	0	8	8	8
Copper 8-quinolinolate																				
0.15%	.4	.4	1.2	2.4	3.3	---	---	---	---	---	0	8	17	25	25	---	---	---	---	---
0.3%	.4	.7	1.0	1.9	2.8	.2	.6	1.5	2.6	3.3	0	0	0	8	8	0	0	8	17	33
0.6%	.3	.5	1.1	2.7	2.7	.4	.5	1.3	2.8	3.3	0	0	8	8	8	0	8	8	17	25
0.3% plus 0.5% gamma benzne hexachloride	---	---	---	---	---	.5	1.0	2.1	3.5	4.5	---	---	---	---	---	0	0	17	33	75
Mineral spirits (aliphatic)	.4	1.3	1.9	3.0	3.8	.9	1.8	2.3	3.5	4.0	0	0	8	21	46	0	8	8	42	67
Orthophenylphenol																				
2.5%	.8	1.2	2.1	3.3	4.3	---	---	---	---	---	0	8	17	33	75	---	---	---	---	---
5.0%	.8	1.7	3.0	3.6	4.4	.4	1.5	2.5	3.8	4.4	0	17	25	58	75	0	8	8	42	83
10.0%	.4	.5	1.3	2.1	3.3	.4	.5	1.6	2.8	3.6	0	8	8	8	42	0	8	8	17	42
Pentachlorophenol																				
2.5%	.3	.5	1.2	2.0	2.6	---	---	---	---	---	0	0	17	17	17	---	---	---	---	---
5.0%	.2	.3	.6	1.2	2.4	.2	.3	.8	1.8	2.3	0	0	0	0	8	0	0	0	0	8
10.0%	.2	.3	.4	1.3	2.1	.0	.4	.4	1.6	2.2	0	0	0	0	8	0	0	0	0	0
5.0% plus 0.5% gamma benzene hexachloride	---	---	---	---	---	.0	.7	.9	2.2	3.0	---	---	---	---	---	0	0	0	0	8
Phenyl mercuric oleate																				
0.15%	.4	1.1	1.7	2.7	3.3	---	---	---	---	---	0	0	8	8	17	---	---	---	---	---
0.3%	.3	.6	1.5	2.3	2.8	.3	.6	1.3	2.6	3.0	0	8	17	17	25	0	0	0	0	17
0.6%	.2	.4	.7	2.0	2.9	.2	.4	1.1	2.7	2.9	0	0	0	0	17	0	0	0	0	17
Product containing 23% zinc naphthenate, 2.5% (coco) dodecyl-amine salt of tetrachlorophenol, and 28.5% water repellent																				
25.0%	.3	.8	1.3	3.0	4.1	---	---	---	---	---	0	0	8	25	67	---	---	---	---	---
37.5%	.3	.3	.6	1.8	2.9	---	---	---	---	---	0	0	0	0	25	---	---	---	---	---
Rosin amine D pentachlorophenate																				
2.75%	.3	.4	1.3	2.0	2.9	---	---	---	---	---	0	0	0	0	33	---	---	---	---	---
5.5%	.3	.5	.6	1.8	2.6	.3	.3	1.1	1.8	2.5	0	0	0	0	17	0	0	8	8	8
11.0%	.3	.5	.8	1.6	2.0	.2	.3	.5	1.5	2.1	0	0	0	0	8	0	0	8	8	8
Tetrachlorophenol																				
2.5%	.4	.6	1.3	2.3	3.3	---	---	---	---	---	0	0	17	17	25	---	---	---	---	---
5.0%	.2	.6	1.0	1.9	2.8	.5	.5	.8	2.0	2.7	0	0	0	0	17	0	8	17	17	17
10.0%	.0	.4	.9	1.5	2.5	.0	.7	.7	1.5	2.3	0	0	0	0	8	0	0	0	0	0
Zinc alkyl sulphonate																				
2.8%	.3	.9	1.4	2.9	3.5	---	---	---	---	---	0	0	8	17	42	---	---	---	---	---
5.7%	.3	.3	.8	2.0	3.0	---	---	---	---	---	0	0	0	0	33	---	---	---	---	---
Zinc naphthenate																				
0.5% Zn	.3	.5	1.2	2.7	3.5	---	---	---	---	---	0	0	0	17	42	---	---	---	---	---
1.0% Zn	.3	.4	.8	1.7	2.8	.4	.6	1.5	2.4	3.3	0	0	0	0	17	0	8	8	17	42
2.0% Zn	.2	.4	.9	2.0	2.8	.2	.6	.8	2.3	2.8	0	0	0	0	8	0	0	8	8	8
Water Solutions, 3-Minute Dips																				
Copper ammonium fluoride																				
5.0%	---	---	---	---	---	.2	.4	1.7	2.8	3.4	---	---	---	---	---	0	0	0	25	42
10.0%	.3	.6	1.7	2.5	2.9	.1	.6	1.3	1.9	2.8	0	0	17	17	17	0	0	8	8	17
20.0%	---	---	---	---	---	.0	.4	.6	1.8	2.9	---	---	---	---	---	0	0	0	0	8
Product containing sodium salts of dimethyl dithiocarbamic acid, 2-mercapto benzothiazole and pentachlorophenol																				
2.5%	---	---	---	---	---	.1	.5	.8	1.3	2.9	---	---	---	---	---	0	0	0	8	17
7.5%	---	---	---	---	---	.0	.3	.9	2.0	3.0	---	---	---	---	---	0	0	0	8	17
Rosin amine D acetate																				
2.5%	---	---	---	---	---	.3	.6	1.1	2.5	3.4	---	---	---	---	---	0	8	8	17	33
5.0%	---	---	---	---	---	.3	.4	.8	1.8	2.9	---	---	---	---	---	0	0	0	0	17
10.0%	---	---	---	---	---	.0	.3	.3	1.9	2.9	---	---	---	---	---	0	0	0	8	33
Sodium pentachlorophenate																				
2.85%	---	---	---	---	---	.4	.6	.8	2.3	2.6	---	---	---	---	---	0	8	8	8	8
5.7%	.2	.3	.5	1.8	2.8	.2	.3	.4	1.5	2.4	0	0	0	0	8	0	0	0	0	8
11.4%	---	---	---	---	---	.1	.3	.4	1.4	1.7	---	---	---	---	---	0	0	0	0	8
2.0% plus borax 3.0%	.0	.2	.3	1.3	2.2	.0	.1	.8	2.3	2.8	0	0	0	0	8	0	0	0	8	17
4.0% plus borax 4.0%	---	---	---	---	---	.0	.2	.7	1.9	2.8	---	---	---	---	---	0	0	0	0	17
Sodium tetrachlorophenate																				
2.85%	.3	.4	1.0	2.0	2.8	---	---	---	---	---	0	8	17	17	17	---	---	---	---	---
5.7%	.3	.4	1.0	1.7	2.5	.0	.3	.7	2.0	2.0	0	0	0	0	17	0	0	0	0	25
Water repellent, 4% solids	.4	1.1	2.1	3.0	3.6	---	---	---	---	---	0	0	8	17	33	---	---	---	---	---
Oil Solution, Pressure Treatment																				
Pentachlorophenol, 5%	.0	.2	.4	.7	1.4	.0	.3	.3	.6	1.7	0	0	0	0	0	0	0	0	0	8
Water Solutions, Pressure Treatments																				
Copperized chromated zinc chloride	---	---	---	---	---	.0	.0	.0	.0	.3	---	---	---	---	---	0	0	0	0	0
Celcure	---	---	---	---	---	.0	.0	.0	.2	.3	---	---	---	---	---	0	0	0	0	0
Tanalith	---	---	---	---	---	.0	.0	.0	.1	.9	---	---	---	---	---	0	0	0	0	0
Untreated																				
	1.8	1.9	2.5	3.4	3.9	---	---	---	---	---	0	2	8	35	61	---	---	---	---	---

[1] Ratings on a basis of 0 (none) to 5 (destroyed).
[2] Percentage of boxes in decry classes 4 and 5.

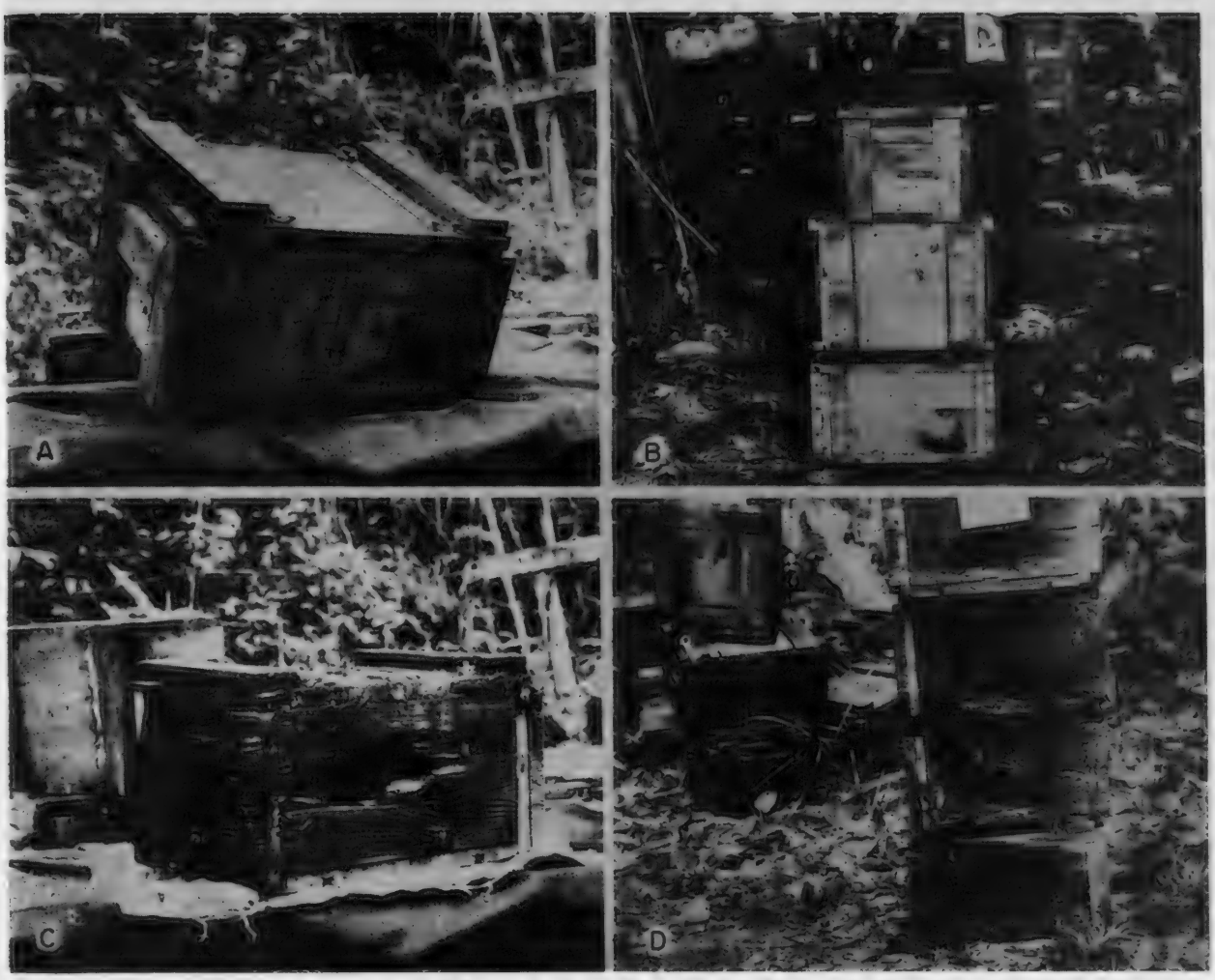


Fig. 3.—Condition of boxes after exposure for 3.5 years in Panama. (A) Box pressure-treated with copperized chromated zinc chloride, showing heavy metal corrosion. Surface is softened, but box is still sound. (B) Boxes given 3-minute dip in copper naphthenate (2 per cent Cu) plus a water repellent. (C) Failure of side of box given 3-minute dip in pentachlorophenol plus water repellent. However, 75 per cent of boxes given this treatment were serviceable after 4.5 years. (D) Failure of all 4 boxes of one treatment in a pile. This is typical of most treatments after 4.5 years.

A decay rating of 1 does not indicate that failure will follow. A rating of 2 indicates that, for the boards involved, failure will eventually occur if only a surface treatment has been used. A rating of 3 indicates well advanced attack, with failure expected soon. Ratings of 4 and 5 indicate that failure has occurred.

In Panama, boxes were tested for strength after 30 months' storage by dropping them, when loaded with 35 pounds of gravel, from a height of 5 feet onto a heavy steel plate. Drops were made successively onto each of the eight box corners. Boxes with a rating of less than 3 for decay or termite attack remained serviceable after 8 drops; those with 3 ratings were badly damaged; those with 4 and 5 ratings were damaged beyond use in 2 to 4 drops. This also applied to strap-corrosion ratings of 4 and 5, as discussed later.

In the Wisconsin exposures, decay was essentially limited to the bottom boards in contact with the soil. In Mississippi and Panama, decay was first noticed, and progressed most rapidly, in the top and bottom boxes of tiers. This was true for treated as well as untreated boxes. A common place for initial decay was under a fallen leaf adhering to the lid of the top box. In storage on untreated soil, decay appeared early on the bottoms of the lower tier of boxes—those in contact with the soil. Treating the soil with DDT in oil delayed bottom decay for 2 years. Bottom decay in Panama was of the black wet-rot type; bottom rot in Mississippi and top rot at both locations were typical Basidiomycete decay. Greatest decay and the common point of failure in boxes between the top and bottom boxes of a tier was the midpoint on the sides of the box.

The condition of boxes after exposure for 3.5 years in Panama is shown in Fig. 3 and after 2 to 4 years in Mississippi in Fig. 4. The amounts of decay occurring in M22 boxes after different storage periods are listed in Tables 2 to 6, inclusive.

Untreated Boxes: If average service life is considered the point at which 60 per cent of the boxes failed, untreated eastern white pine M22 boxes have the following service life when fully exposed to rain-wetting but protected from termites:

Wisconsin—More than 5 years
Mississippi—5.0 years
Panama—3.2 years

Giving the untreated boxes 2 spray coats of paint (TT-E-485b) inside and out reduced the average decay rating after 5.1 years' exposure in Mississippi from 3.9 to 3.2, and the percentage of failures from 61 to 21 (Table 5). Painted boxes were not exposed elsewhere.

Covering a pile of dry boxes in Mississippi prevented decay in untreated boxes during the entire exposure period except at the ground line (Table 4, Fig. 4C). No condensation was ever noted under the tarpaulin.

Wire-bound hardwood veneer boxes had a very short life (2.0 years) when fully exposed in Mississippi (Table 7).

The rate of decay of sapwood and heartwood of 8 wood species commonly used for boxes and crates (Tables 8, 9) showed that none of these species have sufficient natural decay resistance for longtime service when untreated and fully exposed in Mississippi. Eastern white pine heartwood had the slowest decay rate.

Pressure Treatments: Boxes pressure-treated with pentachlorophenol and Tanalith developed small amounts of decay during 5 years of exposure in Wisconsin (Table 6). Those treated with copperized chromated zinc chloride and Celcure remained decay-free. So far, decay has not progressed enough to reveal practical differences between pressure treatments and dips in the Wisconsin exposure.

In Mississippi (Tables 3, 4, and 5), one box pressure-treated with pentachlorophenol failed from decay by *Poria radiculosa*. Except for this the pressure-treated boxes had only minor decay during exposure for 5 years. The pressure treatments were in general more effective than the dip treatments.

In Panama (Table 2), most pressure-treatments did not give better service than the best of the 3-minute dips. Boxes treated with the inorganic salts generally softened at the surface, and by 4.5 years this softening extended to significant depths in many boxes. Boxes treated with copperized chromated zinc chloride were the last to develop this softening and at the end of 4.5 years still had no failures. The heavy rainfall (130 inches) probably caused serious leaching of the

Table 4.—EFFECT OF WATER-TIGHT TARPAULIN COVER ON RATE OF DECAY OF M–22 BOXES EXPOSED IN SOUTHERN MISSISSIPPI

Treatment	Average decay rating[1]										Proportion of failure[2]									
	Uncovered pile					Covered piles[3]					Uncovered pile					Covered piles				
	1.2 yr.	2.2 yr.	3.2 yr.	4.2 yr.	5.1 yr.	1.2 yr.	2.2 yr.	3.2 yr.	4.2 yr.	5.1 yr.	1.2 yr.	2.2 yr.	3.2 yr.	4.2 yr.	5.1 yr.	1.2 yr.	2.2 yr.	3.2 yr.	4.2 yr.	5.1 yr.
											Per cent									
Oil Solutions, 3-Minute Dips																				
Copper naphthenate (1.0% Cu)+WR	0.2	0.4	0.5	1.0	2.1	0.0	0.0	0.0	0.0	0.6	0	0	0	8	17	0	0	0	0	8
Copper 3-phenyl salicylate, 2.5%+WR	.2	.5	1.1	2.5	3.3	.0	.0	.0	.0	.4	0	0	0	8	42	0	0	0	0	8
Copper 8-quinolinolate, 0.3%+WR	.4	.7	1.0	1.9	2.8	.0	.0	.0	.2	.6	0	0	0	8	8	0	0	0	0	8
Mineral spirits (aliphatic), 100%	.9	1.8	2.3	3.5	4.0	.0	.0	.0	.0	.1	0	8	8	42	67	0	0	0	0	0
Orthophenylphenol, 5%+WR	.8	1.7	3.0	3.6	4.4	.0	.0	.0	.3	.4	0	17	25	58	75	0	0	0	0	8
Pentachlorophenol, 5%+WR	.2	.3	.6	1.2	2.4	.0	.0	.0	.2	.4	0	0	0	0	8	0	0	0	0	8
Phenyl mercuric oleate, 0.3%+WR	.3	.6	1.5	2.3	2.8	.0	.0	.0	.3	.4	0	8	17	17	25	0	0	0	0	8
Rosin amine D pentachlorophenate, 5.5%+WR	.3	.5	.6	1.8	2.6	.0	.0	.0	.0	.6	0	0	0	0	17	0	0	0	0	0
Zinc naphthenate (1% Zn)+WR	.3	.4	.8	1.7	2.8	.0	.0	.0	.0	.5	0	0	0	0	17	0	0	0	0	8
Water repellent (10% solids)	.4	1.3	1.9	3.0	3.8	.0	.0	.0	.1	.4	0	0	8	21	46	0	0	0	0	0
Water Solutions, 3-Minute Dips																				
Copper ammonium fluoride, 10%	.1	.6	1.3	1.9	2.8	.0	.1	.1	.0	.3	0	0	8	8	17	0	0	0	0	
Sodium pentachlorophenate, 2%, plus borax, 3%	.0	.1	.8	2.3	2.8	.0	.0	.0	.0	.1	0	0	0	8	17	0	0	0	0	
Water Solutions, Pressure Treatments																				
Copperized chromated zinc chloride	.0	.0	.0	.0	.3	.0	.0	.0	.0	.1	0	0	0	0	0	0	0	0	0	0
Celcure	.0	.0	.0	.2	.3	.0	.0	.0	.0	.3	0	0	0	0	0	0	0	0	0	0
Tanalith	.0	.0	.0	.1	.9	.0	.0	.0	.0	.1	0	0	0	0	0	0	0	0	0	0
Untreated																				
	1.8	1.9	2.5	3.4	3.9	.0	+	.1	.3	.9	0	2	8	35	61	0	0	0	0	4

[1]Ratings on a basis of 0 (none) to 5 (destroyed). "+" indicates less than 0.05.
[2]Percentage of boxes in decay classes 4 and 5.
[3]All decay caused by Poria incrassata on bottom boxes.

Table 5.—EFFECT OF 2 COATS OF PAINT (TT–E–485b), APPLIED AFTER TREATMENT, ON RATE OF DECAY OF M–22 BOXES EXPOSED WITHOUT TARPAULIN COVER IN SOUTH MISSISSIPPI

Treatment	Average decay rating[1]										Proportion of failure[2]									
	Painted					Unpainted					Painted					Unpainted				
	1.2 yr.	2.2 yr.	3.2 yr.	4.2 yr.	5.1 yr.	1.2 yr.	2.2 yr.	3.2 yr.	4.2 yr.	5.1 yr.	1.2 yr.	2.2 yr.	3.2 ur.	4.2 yr.	5.1 yr.	1.2 yr.	2.2 yr.	3.2 yr.	4.2 yr.	5.1 yr
											Per cent									
Oil Solutions, 3-Minute Dips																				
Copper naphthenate (1.0% Cu) plus WR	0.0	0.0	0.2	0.3	0.6	0.2	0.4	0.5	1.0	2.1	0	0	0	0	0	0	0	0	8	17
Copper 3-phenyl salicylate, 2.5% plus WR	.0	.0	.0	.4	1.5	.2	.5	1.1	2.5	3.3	0	0	0	0	0	0	0	0	8	42
Copper 8-quinolinolate, 0.3% plus WR	.2	.2	.4	.5	1.8	.4	.7	1.0	1.9	2.8	0	0	0	0	8	0	0	0	8	8
Mineral spirits (aliphatic) 100%	.3	.7	1.0	2.1	3.0	.9	1.8	2.3	3.5	4.0	0	0	0	8	33	0	8	8	42	67
Orthophenylphenol, 5.0% plus WR	.0	.3	.9	1.6	2.1	.8	1.7	3.0	3.6	4.4	0	0	0	0	8	0	17	25	58	75
Pentachlorophenol, 5.0% plus WR	.0	.2	.3	.7	1.4	.2	.3	.6	1.2	2.4	0	0	0	0	0	0	0	0	0	8
Phenyl mercuric oleate, 0.3% plus WR	.0	.0	.3	.5	1.3	.3	.6	1.5	2.3	2.8	0	0	0	0	0	0	8	17	17	25
Product containing 23% zinc naphthenate, 2.5% (coco) dodecyl-amine salt of tetrachlorophenol, and 28.5% water repellent, 37.5%	.0	.0	.3	1.2	1.8	.3	.3	.6	1.8	2.9	0	0	0	17	17	0	0	0	0	25
Rosin amine D pentachlorophenate, 5.5% plus WR	.0	.0	.2	.7	1.5	.3	.5	.6	1.8	2.6	0	0	0	0	0	0	0	0	0	17
Zinc alkyl sulphonate, 5.7% plus WR	.3	.6	.9	1.3	2.3	.3	.3	.8	2.0	3.0	0	0	0	0	8	0	0	0	0	33
Zinc naphthenate (1.0% Zn) plus WR	.2	.2	.2	1.2	1.9	.3	.4	.8	1.7	2.8	0	0	0	0	8	0	0	0	0	17
Water repellent (10% solids)	.1	.2	.2	.8	1.8	.4	1.3	1.9	3.0	3.8	0	0	0	c	8	0	0	8	21	46
Water Solutions, 3-Minute Dips																				
Copper ammonium fluoride, 10.0%	.0	.0	.0	.3	1.0	.1	.6	1.3	1.9	2.8	0	0	0	0	0	0	0	8	8	17
Rosin amine D acetate, 5.0%	.3	.6	.6	1.0	2.4	.3	.4	.8	1.8	2.9	0	0	0	8	25	0	0	0	0	17
Sodium pentachlorophenate, 5.7%	.0	.0	.0	.3	.6	.2	.3	.4	1.5	2.4	0	0	0	0	0	0	0	0	0	8
Sodium pentachlorophenate, 2.0% plus borax, 3.0%	.0	.0	.0	.4	.7	.0	.1	.8	2.3	2.8	0	0	0	0	0	0	0	0	8	17
Sodium tetrachlorophenate, 5.7%	.0	.3	.3	.6	1.1	.0	.3	.7	2.0	2.8	0	0	0	0	0	0	0	0	0	25
Oil Solution, Pressure Treatment																				
Pentachlorophenol, 5%	.0	.0	.0	.5	.7	.0	.3	.3	.6	1.7	0	0	0	0	0	0	0	0	0	8
Untreated																				
	.2	.7	1.0	1.9	3.2	1.8	1.9	2.5	3.4	3.9	0	0	4	8	21	0	2	8	35	61

[1]Ratings on a basis of 0 (none) to 5 (destroyed).
[2]Percentage of boxes in decay classes 4 and 5.

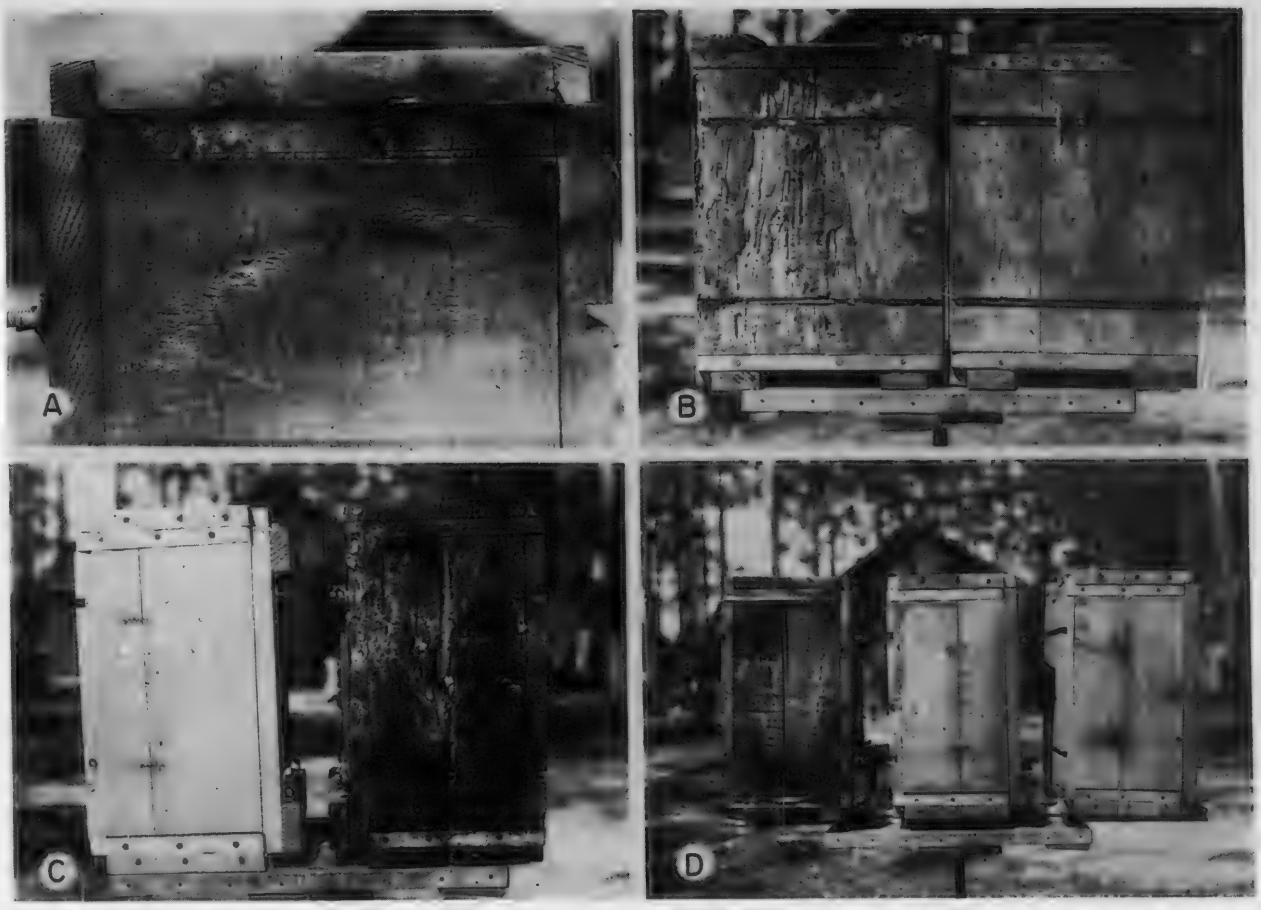


Fig. 4.—Condition of M22 boxes after exposure in Mississippi. (A) Strap failure on box pressure-treated with copperized chromated zinc chloride, 3 years' exposure. (B) Boxes dipped in 5 per cent pentachlorophenol plus water repellent and exposed for 2 years on untreated soil (termite attack) and DDT-treated soil (sound). (C) Untreated boxes after 4 years' exposure under cover (sound) and in exposed pile (decayed). (D) Conditions of boxes in fully exposed pile after 3 years; from left to right: Untreated, and 3-minute dips in 5 per cent pentachlorophenol plus water repellent and copper naphthenate (2 per cent Cu).

Table 6.—RATE OF DECAY OF M–22 BOXES EXPOSED IN WISCONSIN, MISSISSIPPI, AND PANAMA

Treatment	Average decay rating[1]												Proportion failure[2]											
	Wisconsin			Mississippi					Panama				Wisconsin			Mississippi					Panama			
	3 yr.	4 yr.	5 yr.	1.2 yr.	2.2 yr.	3.2 yr.	4.2 yr.	5.1 yr.	1.5 yr.	2.5 yr.	3.5 yr.	4.5 yr.	3 yr.	4 yr.	5 yr.	1.2 yr.	2.2 yr.	3.2 yr.	4.2 yr.	5.1 yr.	1.5 yr.	2.5 yr.	3.5 yr.	4.5 yr.
													Per cent											
Oil Solutions, 3-Minute Dips																								
Copper naphthenate (1% Cu) plus WR	0.3	0.3	0.5	0.2	0.4	0.5	1.0	2.1	0.4	1.3	2.4	3.6	0	0	0	0	0	0	8	17	0	0	23	35
Copper pentachlorophenate, 5% plus WR	.2	.3	.5	.2	.2	.2	.8	1.9	.3	1.5	2.6	3.0	0	0	0	0	0	0	0	8	0	0	9	9
Copper 3-phenyl salicylate, 2.5% plus WR	.4	.6	1.0	.2	.5	1.1	2.5	3.3	.5	2.0	3.8	4.5	0	0	0	0	0	0	8	42	0	10	50	75
Copper 8-quinolinolate, 0.3% plus WR	.5	.4	.8	.4	.7	1.0	1.9	2.8	.7	2.3	3.9	4.4	0	0	0	0	0	0	8	8	0	17	57	77
Orthophenylphenol, 5% plus WR	.6	.5	.7	.8	1.7	3.0	3.6	4.4	1.0	2.2	3.5	4.0	0	0	0	0	17	25	58	75	4	9	35	62
Pentachlorophenol, 5% plus WR	.7	.6	1.0	.2	.3	.6	1.2	2.4	.4	1.9	2.9	3.6	0	0	0	0	0	0	0	8	0	5	25	25
Phenyl mercuric oleate, 0.3% plus WR	.6	.6	1.0	.3	.6	1.5	2.3	2.8	.9	2.4	4.5	4.6	0	0	0	0	8	17	17	25	0	5	65	89
Product containing 23% zinc naphthenate, plus dodecyl amine salt of tetrachlorophenol, 37.5% plus WR	.7	.6	1.3	.3	.3	.6	1.8	2.9	1.3	3.4	4.9	4.9	0	0	8	0	0	0	0	25	0	30	90	100
Rosin amine D pentachlorophenate, 5.5% plus WR	.5	.6	1.0	.3	.5	.6	1.8	2.6	.3	1.9	2.9	3.6	0	0	0	0	0	0	0	17	0	0	18	33
Tetrachlorophenol, 5% plus WR	.4	.4	.8	.2	.6	1.0	1.9	2.8	1.2	2.9	4.0	4.5	0	0	8	0	0	0	0	17	0	10	50	90
Water repellent only	.8	.7	.8	.4	1.3	1.9	3.0	3.8	2.1	3.3	4.5	4.8	0	0	0	0	0	8	21	46	0	28	84	91
Zinc alkyl sulphonate, 5.7% plus WR	.6	.6	.8	.3	.3	.8	2.0	3.0	1.2	2.8	4.6	5.0	0	0	0	0	0	0	0	33	0	30	70	100
Zinc naphthenate (1% Zn) plus WR	.6	.8	.8	.3	.4	.8	1.7	2.8	.5	2.6	4.1	4.7	0	0	0	0	0	0	0	17	0	16	63	88
Water Solutions, 3-Minute Dips																								
Copper ammonium fluoride, 10%	.2	.5	.6	.1	.6	1.3	1.9	2.8	1.1	3.3	4.5	4.6	0	0	0	0	0	8	8	17	0	5	77	88
Rosin amine D acetate, 5%	.3	.6	.8	.3	.4	.8	1.8	2.9	1.2	3.3	4.5	4.9	0	0	0	0	0	0	0	17	0	36	82	100
Sodium pentachlorophenate, 5.7%	.3	.5	.8	.2	.3	.4	1.5	2.4	.5	2.0	2.9	3.6	0	0	0	0	0	0	0	8	0	0	9	44
Sodium pentachlorophenate, 2.0% plus borax, 3%	.4	.4	1.0	.0	.1	.8	2.3	2.8	.5	2.3	3.4	3.7	0	0	0	0	0	0	8	17	0	18	32	48
Sodium tetrachlorophenate, 5.7%	.4	.6	1.0	.0	.3	.7	2.0	2.8	.6	2.4	3.6	3.8	0	0	0	0	0	0	0	25	0	0	30	56
Oil Solution, Pressure Treatment																								
Pentachlorophenol, 5%	.5	.4	.7	.0	.3	.3	.6	1.7	.5	1.7	2.0	2.9	0	0	0	0	0	0	0	8	0	13	19	20
Water Solutions, Pressure Treatments																								
Copperized chromated zinc chloride	.0	.0	.0	.0	.0	.0	.0	.3	.1	.2	.7	2.4	0	0	0	0	0	0	0	0	0	0	0	0
Tanalith	.3	.3	.6	.0	.0	.0	.1	.9	.3	1.3	3.1	3.2	0	0	0	0	0	0	0	0	0	0	13	13
Celcure	.0	.0	.0	.0	.0	.0	.2	.3	.0	.4	1.6	2.8	0	0	0	0	0	0	0	0	0	0	11	19
Untreated																								
	.8	1.5	1.6	1.8	1.9	2.5	3.4	3.9	2.1	3.1	4.3	4.8	0	0	8	0	2	8	35	61	6	25	81	88

[1] Ratings on a basis of 0 (none) to 5 (destroyed).
[2] Percentage of boxes in decay classes 4 and 5.

Table 7.—EFFECTIVENESS OF TWO FUNGICIDES IN PREVENTING DECAY IN WIRE-BOUND VENEER CRATES EXPOSED UNDER PARTIAL HARDWOOD SHADE ON DDT-TREATED SOIL IN MISSISSIPPI

Treatment	Solution absorbed[1] lb./cu.ft.	Average decay rating[2] 1.1 yr.	2.0 yr.	3.1 yr.	Proportion of failure[3] 1.1 yr.	2.0 yr.	3.1 yr.
					Per cent		
5% pentachlorophenol+water repellent, 3-minute dip	12.4	0.1	0.4	1.2	0	0	0
5% pentachlorophenol+water repellent, 10-minute soak	5.5	.0	.2	.8	0	0	0
Copper naphthenate (2% Cu), 10-second dip	3.9	.0	.0	.4	0	0	0
Copper naphthenate (2% Cu), 3-minute dip	9.8	.0	.0	.5	0	0	0
Untreated	----	2.7	3.7	4.5	10	60	100

[1]Excluding separators. There was large variation from crate to crate depending mainly on the amount of white-pine heartwood present. In the treated crates there were no ratings above "2", i.e. they are essentially decay free.
[2]Ratings on a basis of 0 (none) to 5 (destroyed).
[3]Percentage of boxes in decay classes 4 and 5.

Table 9.—RELATIVE DECAY RATE OF M-22 BOXES MADE OF EASTERN WHITE PINE AND SOUTHERN YELLOW PINE EXPOSED IN SOUTH MISSISSIPPI

Treatment	Average decay rating[1]: Eastern white pine 1.2 yr.	2.2 yr.	3.2 yr.	4.2 yr.	Southern yellow pine 1.2 yr.	2.2 yr.	3.2 yr.	4.2 yr.
Copper 8-quinolinolate, 0.3%	0.2	0.6	1.5	2.6	0.5	1.0	2.8	3.5
Pentachlorophenol, 5%+WR	.2	.3	.6	1.2	.2	.4	.6	1.7
Untreated	1.8	1.9	2.5	3.4	2.0	2.0	4.0	4.3

Treatment	Proportion of failure[2]: Eastern white pine 1.2 yr.	2.2 yr.	3.2 yr.	4.2 yr.	Southern yellow pine 1.2 yr.	2.2 yr.	3.2 yr.	4.2 yr.
	Per cent							
Copper 8-quinolinolate, 0.3%	0	0	8	17	0	0	17	17
Pentachlorophenol, 5%+WR	0	0	0	0	0	0	0	8
Untreated	0	2	8	35	0	0	58	58

[1]Ratings on a basis of 0 (none) to 5 (destroyed).
[2]Percentage of boxes in decay classes 4 and 5.

Table 10.—EFFECT OF LENGTH OF IMMERSION ON EFFECTIVENESS OF 2 PRESERVATIVES ON SIMULATED BOXES OF SOUTHERN PINE SAPWOOD

Treatment	Solution absorbed lb./cu.ft.	Average decay rating[1] 1.5 yr.	2.7 yr.	3.4 yr.	4.4 yr.	Proportion of failure[2] 1.5 yr.	2.7 yr.	3.4 yr.	4.4 yr.
						Per cent			
5% pentachlorophenol plus WR in mineral spirits									
0.5 min.	1.5	0.0	2.2	2.8	3.3	0	0	0	10
1 min.	1.5	.0	2.2	2.6	3.2	0	0	0	10
3 min.	2.0	.0	.4	2.2	2.7	0	0	0	0
10 min.	2.2	.2	1.7	2.5	3.3	0	0	0	0
4% sodium pentachlorophenate plus 4% borax in water									
0.5 min.	1.5	1.0	2.2	2.6	3.2	0	0	0	20
1 min.	1.7	.0	1.0	2.7	3.3	0	0	0	30
3 min.	2.0	.9	2.1	2.7	3.5	0	0	0	20
10 min.	2.1	.0	1.7	2.4	3.5	0	0	0	30
Untreated	.0	3.2	3.6	4.4	5.0	0	55	90	100

[1]Ratings on a basis of 0 (none) to 5 (destroyed).
[2]Percentage of boxes in decay classes 4 and 5.

Table 8.—EFFECTIVENESS OF 5 PERCENT PENTACHLOROPHENOL PLUS A WATER REPELLENT ON SIMULATED BOXES MADE OF DIFFERENT WOOD SPECIES

Wood species	Solution absorbed lb./cu. ft.	Average decay rating[1]: Treated 1.5 yr.	2.7 yr.	3.4 yr.	4.4 yr.	Untreated 1.5 yr.	2.7 yr.	3.4 yr.	4.4 yr.	Proportion of failure[2]: Treated 1.5 yr.	2.7 yr.	3.4 yr.	4.4 yr.	Untreated 1.5 yr.	2.7 yr.	3.4 yr.	4.4 yr.
										Per cent							
Southern yellow pine, sapwood	1.9	0.0	0.9	1.1	1.8	3.1	3.9	4.3	5.0	0	0	0	10	0	80	100	100
Southern yellow pine, mostly heartwood	1.0	.0	.0	.4	1.1	3.2	4.3	5.0	5.0	0	0	0	0	0	80	100	100
Eastern white pine, sap and heartwood	.9	.0	.0	.9	1.7	2.0	3.0	3.5	4.3	0	0	0	0	0	10	30	80
Ponderosa pine, heart and sapwood	2.8	.0	.0	.4	1.7	2.5	4.1	4.7	5.0	0	0	0	0	0	80	100	100
Western hemlock, mostly heartwood	.9	.0	.2	.3	2.2	2.5	4.3	5.0	5.0	0	0	0	0	0	80	100	100
Douglas fir, mostly heartwood	1.0	.0	.1	.1	.4	2.4	3.8	4.2	5.0	0	0	0	0	10	60	80	100
Yellow poplar, sapwood	2.3	.0	.4	1.9	2.6	3.7	4.8	5.0	5.0	0	0	0	0	70	90	100	100
Yellow poplar, mostly heartwood	1.5	.0	.7	1.4	2.3	3.3	4.6	5.0	5.0	0	0	0	0	30	80	100	100
Sap gum (Sweetgum sapwood)	1.7	.0	1.4	2.2	3.0	4.1	5.0	5.0	5.0	0	0	0	0	50	100	100	100
Red gum (Sweetgum heartwood)	1.4	.0	.4	1.5	2.3	3.1	3.5	4.0	5.0	0	0	0	0	20	50	100	100
Tupelo, mostly sapwood	2.9	.0	.0	.7	2.3	3.9	4.8	5.0	5.0	0	0	0	0	80	100	100	100
Misc. northern conifers (from M-22 boxes)	---	.0	.0	.1	1.5	2.3	3.5	4.2	4.8	0	0	0	0	0	10	70	100

[1]Ratings on a basis of 0 (none) to 5 (destroyed).
[2]Percentage of boves in decay classes 4 and 5.

salts in boxes exposed in Panama. With Tanalith, in fact, many of the boxes that failed had slightly higher than average initial retention.

Pressure treatments with 5 per cent pentachlorophenol and 5 per cent pentachlorophenol plus a water repellent likewise did not give a high order of protection in Panama (Table 2). In interpreting these Panama results three factors should be considered: 1) Individual boxes varied in amount of heartwood, which is less easily treated, and thus caused large variations in retentions; 2) some of the wood species (spruce and balsam fir) have sapwood refractory to treatment, and others (as aspen) treat erratically; and 3) heavy blooming occurred, so that actual retentions were lower than indicated. An analysis showed a highly significant correlation (at the 0.1 per cent level) between pentachlorophenol retentions and decay rating in Panama. This is illustrated by the following data for 5 per cent pentachlorophenol:

Decay Class	Absorption of Solution: Range	Average
2	3.9–7.6	6.6
3	3.8–8.8	5.7
4 and 5	3.3–3.9	3.6

Three-minute Dips: In Wisconsin, six dip treatments permitted only a few scattered decay spots during 5 years' exposure: Copper naphthenate (1 per cent Cu), 5 per cent copper pentachlorophenate, 5 per cent rosin amine D acetate, 10 per cent copper ammonium fluoride, 5 per cent orthophenylphenol, and 2 per cent sodium pentachlorophenate plus 3 per cent borax. The first three had lower average decay ratings than two of the pressure treatments, but the differences probably are not significant. The other treatments permitted general decay and weakening of the bottom boards in contact with the soil.

At Gulfport (Table 3, Fig. 4D), copper naphthenate (2 per cent Cu), 5 per cent copper pentachlorophenate,

Fig. 5.—Simulated boxes of 4 wood species after exposure for 3.7 years in Mississippi. In each pair, the untreated unit is severely decayed and the one given a 3-minute dip in 5 per cent pentachlorophenol plus a water repellent is sound. (A) Douglas-fir heartwood, (B) southern yellow pine sapwood, (C) western hemlock sapwood and heartwood, and (D) sweetgum sapwood.

and 11.4 per cent sodium pentachlorophenate gave the best protection to boxes in piles fully exposed for 5 years. Copper naphthenate (0.5 and 1 per cent Cu), 5 and 10 per cent pentachlorophenol, 11 per cent rosin amine D pentachlorophenate, 10 per cent tetrachlorophenol, zinc naphthenate (2 per cent Zn), and 5.7 per cent sodium pentachlorophenate also gave good protection. A high percentage of failures occurred with copper 3-phenyl salicylate, copper 8-quinolinolate, orthophenylphenol, zinc alkyl sulphonate, sodium tetrachlorophenate, the product containing zinc naphthenate and dodecyl-amine salt of tetrachlorophenol, and low concentrations of rosin amine D pentachlorophenate, tetrachlorophenol, copper ammonium fluoride, and zinc naphthenate (0.5 and 1 per cent Zn). Other treatments were intermediate in effectiveness.

In Panama (Table 2) only copper naphthenate (2 per cent Cu), 5 per cent copper pentachlorophenate, and 10 per cent tetrachlorophenol gave appreciable control (Figs. 3B, C, D) for 4.5 years.

Five per cent pentachlorophenol plus a water repellent markedly reduced the decay rate of all wood species upon which it was tested (Tables 8, 9, Fig. 5). It was particularly effective on Douglas-fir heartwood. Generally, the treatment was less effective on the hardwood species than on the coniferous woods. McKnight (4) has shown that preservatives in non-swelling solvents (as used in the present tests) are less effective against white rotters than brown rotters. In these tests the coniferous woods were rotted by the brown-rotter *Lenzites saepiaria,* the hardwoods by the white-rotter *Polyporus versicolor.*

With both simulated boxes (Table 10) and M22 boxes (Table 11), varying the immersion period from 5 seconds to 10 minutes had no appreciable effect on rate of decay in Mississippi. In other tests (6) with less severe exposure simulating exterior woodwork of buildings, 15-minute immersions were definitely more effective than 3-minute dips, and the latter were appreciably better than 5-second dips.

Wood treated while green retained little preservative and decayed faster than wood treated when dry, particularly when the toxicant was applied in an oil solution (Table 12). There were only minor differences in decay rate of wood treated when partially seasoned, air-dried, and kiln-dried except when infected with fungi prior to treatment. Partially dried and infected wood treated with the oil solution decayed at a significantly faster rate than uninfected wood treated at the same moisture content. This was not true when the fungicide was in water solution or when infected wood was fully air-dried before treatment.

The addition of water repellents did not consistently or importantly affect decay rate (Tables 3, 13). This was in contrast to the salutary effects of repellents on siding and other exterior woodwork (6, 7), where they can prevent the capillary movement of rainwater into joints. Under the more severe conditions in a fully exposed

pile of boxes and where water content of the wood gradually builds up, the repellent apparently has little or no effect on decay rate.

Though paint (2 spray coats of TT–E–485b) did not appreciably reduce moisture content, it did retard decay rate (Tables 5, 14). The average decay rating and the percentage of failure of painted M22 boxes after 5.1 years' exposure were significantly lower except where the preservative was rosin amine D acetate (Table 5). Under the more severe exposure of the simulated box tests (Table 14), paint still had a beneficial effect in conjunction with the better preservatives (pentachlorophenol and copper naphthenate), but its effect had largely disappeared at the end of 4.6 years' exposure with copper 8-quinolinolate.

After 4.5 years' exposure, fungicides applied in a No. 2 fuel oil were slightly more effective than the same fungicides applied in mineral spirits (Table 15). The differences, however, were not of a practical degree. In other tests greater differences have been reported (6).

Corrosion of Hardware

Hardware of the M22 box consists of non-galvanized nails; galvanized strapping; and dip-coated U-bolts, wing nuts, and cross bars (Fig. 3). After 38 to 42 months' exposure, each box was rated for corrosion of hardware, on the following scale:

0	None evident
1	Slight amount of white corrosion
2	Moderate amount of white or small amount of red corrosion
3	Considerable corrosion but no danger that straps will fail in ordinary use. Wing nuts still removable by hand
4	Strapping near failure without stress; would probably fail in drop test. Wing nuts not removable by hand
b	Failure without stress

Average corrosion ratings are listed in Tables 16, 17, 18, and 19.

Failure of U-bolts, bars, and wing nuts was limited to boxes treated with copper ammonium fluoride and exposed in Mississippi and Panama. The following treatments, however, put more than 20 per cent of boxes in corrosion class 4, that is, significantly more than the untreated: *In Panama:* copper pentachlorophenate, pentachlorophenol, rosin amine D pentacholophenate, sodium pentacholorphenate (with and without borax), sodium tetrachlorophenate, copperized chromated zinc chloride, and Celcure. *In Mississippi*: The product containing sodium salts of dimethyl dithiocarbamic acid, 2-mercapto benzothiazole and pentachlorophenol; sodium tetrachlorophenate; copperized chromated zinc chloride; and Celcure. *In Wisconsin*: None.

Because the U-bolts, bars, and wing nuts were removed for pressure treating, serious corrosion of these items on boxes pressure-treated with the inorganic salts was due to salt in the wood, or leached from the wood, and not to direct contact with the treating solutions as occurred in the dip treatment.

Corrosion of the strapping was somewhat affected by adjacent treatments in the piles. Thirty-nine boxes from seven different chemical treatments were rated separately for corrosion of strapping on the side adjacent to boxes treated with copper ammonium fluoride and on the opposite side. In 31 of the 39 comparisons, greater corrosion occurred on the side next to the fluoride treatment, the average increase being 42 per cent. This effect, however, has not caused an otherwise satisfactory treatment to be classed as a failure.

Usually the preservative treatment had no significant effect on strap corrosion, but several treatments seriously increased corrosion and two significantly reduced it.

In Mississippi and Panama, exposures with dangerously high amounts of strap failure (average rating of 3.8 or above in comparison to 2.3 for the untreated) were found on boxes treated with:

Copper ammonium fluoride, all concentrations and conditions.

Copperized chromated zinc chloride, in uncovered piles (Figs. 3 and 4).

Celcure, in uncovered piles.

Product containing sodium salts of dimethyl dithiocarbamic acid, 2-mercapto benzothiazole, and pentachlorophenol at 7.5 per cent concentrations in uncovered piles.

In addition, the following treatments had significant numbers of straps with "4" ratings in Mississippi and Panama: Copper pentachlorophenate plus water repellent, 10 per cent tetrachlorophenol, sodium pentachlorophenate (alone or with borax; particularly severe with water repellent added), and sodium tetrachlorophenate.

In Wisconsin, no treatment caused serious corrosion of U-bolts; the highest average rating was 2.7 for the 3 boxes dipped in copper ammonium fluoride and exposed in contact with the soil. Copper ammonium fluoride (average rating 5.0) and copperized chromated zinc chloride (average rating 4.4) were the only treatments that caused strap failures, but treatments with sodium pentachlorophenate (alone and with borax), sodium tetrachlorophenate, Celcure, and Tanalith resulted in significantly higher corrosion of strapping than occurred on untreated boxes.

Table 11.—EFFECT OF LENGTH OF IMMERSION ON THE EFFECTIVENESS OF 6 PRESERVATIVE SOLUTIONS ON M-22 BOXES MADE OF NORTHERN CONIFEROUS WOODS

Treatment	Solution absorbed lb./cu. ft.	Average decay rating[1] 2.1 yr.	3.3 yr.	3.9 yr.	4.9 yr.
10% copper ammonium fluoride in water					
5 sec.	1.1	0.4	1.1	2.4	3.3
10 sec.	1.2	.4	.7	2.2	3.5
1 min.	1.6	.8	1.0	2.4	3.5
2 min.	1.5	.2	.8	1.8	2.7
3 min.	1.7	.3	.7	2.3	3.8
10 min.	1.9	.7	.8	2.2	3.5
5.7% sodium pentachlorophenate in water					
5 sec.	1.5	.3	1.0	2.7	3.1
10 sec.	1.5	.5	1.3	2.5	3.0
1 min.	1.7	.0	1.7	2.5	2.8
2 min.	1.7	.0	.7	2.0	2.5
3 min.	1.8	.0	.8	2.3	2.6
10 min.	2.3	.2	.8	1.7	3.0
0.3% copper 8-quinolinolate plus water repellent in mineral spirits					
5 sec.	1.0	.5	1.0	2.4	3.0
10 sec.	.9	.5	1.0	2.6	3.3
1 min.	1.3	.5	1.8	2.5	3.3
2 min.	1.1	1.0	.8	2.5	3.3
3 min.	1.1	.5	1.2	2.5	3.3
10 min.	1.3	.3	.8	2.4	3.3
Copper naphthenate (1% Cu) plus water repellent in mineral spirits					
5 sec.	1.0	.0	.0	1.0	2.0
10 sec.	1.0	.0	.3	1.4	2.5
1 min.	1.2	.0	.3	1.2	2.2
2 min.	1.1	.0	.0	1.7	2.3
3 min.	1.1	.0	.0	1.0	2.1
10 min.	1.2	.0	.3	1.2	2.2
5% pentachlorophenol in mineral spirits					
5 sec.	.9	.7	.7	1.8	2.7
10 sec.	.8	.7	1.3	2.3	2.6
1 min.	1.0	.3	1.3	2.3	2.6
2 min.	1.0	.0	.8	2.3	1.5
3 min.	1.2	.0	.7	1.8	2.7
10 min.	1.3	.0	.8	1.3	2.4
5% pentachlorophenol plus water repellent in mineral spirits					
5 sec.	.9	.3	1.2	1.8	2.6
10 sec.	1.0	.0	1.0	2.3	2.8
1 min.	1.0	.0	.7	2.0	2.8
2 min.	1.1	.7	.8	1.8	2.9
3 min.	1.3	.0	.5	2.0	2.8
10 min.	1.5	.0	.7	1.8	2.5

[1] Ratings on a basis of 0 (none) to 5 (destroyed). No failures after 4.9 years' exposure.

Table 12.—EFFECT OF WOOD MOISTURE CONTENT AND FUNGUS INFECTIONS PRIOR TO TREATMENT ON THE RATE OF DECAY OF PINE SAPWOOD SIMULATED BOXES GIVEN 3-MINUTE DIPS IN PRESERVATIVE TREATMENTS

Treatment and wood condition	Moisture content Per cent	Solution absorbed lb./cu. ft.	Average decay rating[1] 1.3 yr.	2.5 yr.	3.2 yr.	4.3 yr.	Proportion of failure[2] 1.3 yr.	2.5 yr.	3.2 yr.	4.3 yr.
							Per cent			
4% sodium pentachlorophenate + 4% borax										
Green, uninfected	110	0.7	0.2	0.5	2.5	3.7	0	0	20	60
Partially dried, uninfected	40[4]	1.5	.0	.2	2.3	3.5	0	0	0	30
Partially dried, infected[3]	40[4]	1.7	.0	.0	2.8	3.8	0	0	0	50
Air dried, uninfected	14	1.9	.1	.6	1.8	3.2	0	0	10	40
Air dried, infected[3]	14	2.1	.0	.7	2.1	3.5	0	0	10	40
Kiln dried, uninfected	9	2.1	.0	.6	1.5	3.0	0	0	0	0
5% pentachlorophenol + water repellent										
Green, uninfected	110	.4	.0	1.2	2.7	3.8	0	0	0	50
Partially dried, uninfected	40[4]	1.6	.0	.7	1.9	3.5	0	0	0	30
Partially dried, infected[3]	40[4]	2.1	1.4	2.6	3.1	3.9	0	0	30	80
Air dried, uninfected	14	2.6	.0	.2	1.0	2.1	0	0	0	0
Air dried, infected[3]	14	2.1	.1	.0	.9	2.4	0	0	0	0
Kiln dried, uninfected	9	2.1	.0	.1	1.0	2.3	0	0	0	0
Untreated										
Green, uninfected	110	---	.0	2.7	3.5	4.4	0	0	70	100
Partially dried, uninfected	40[4]	---	.8	1.8	3.1	4.3	0	0	20	100
Partially dried, infected[3]	40[4]	-	2.9	3.1	4.0	4.9	0	10	90	100
Air dried, uninfected	14	---	.1	3.0	3.6	4.3	0	10	40	100
Air dried, infected[3]	14	.	2.4	2.8	3.9	4.8	0	10	70	100
Kiln dried, uninfected	9	..	2.3	2.7	3.8	4.7	0	0	60	100

[1]Ratings on a basis of 0 (none) to 5 (destroyed).
[2]Percentage of boxes in decay classes 4 and 5.
[3]Mainly stain, some mold, and probably incipient decay.
[4]Average moisture content. Surfaces were about 30%; interiors about 65%.

Table 13.—EFFECT OF WATER REPELLENTS APPLIED AS 3-MINUTE DIPS ON THE DECAY RATE OF PINE SAPWOOD IN SIMULATED BOXES

Treatment	Solution absorbed lb./cu. ft.	Average decay rating[1] 1.0 yr.	2.9 yr.	3.6 yr.	4.6 yr.	Proportion of failure[2] 1.9 yr.	2.9 yr.	3.6 yr.	4.6 yr.
						Per cent			
3% orthophenylphenol	2.0	3.1	3.1	3.9	4.8	0	10	50	100
3% orthophenylphenol + water repellent[3]	2.0	2.0	2.7	3.5	5.0	0	10	30	100
5% orthophenylphenol	2.2	1.6	2.2	3.9	4.4	0	10	50	70
5% orthophenylphenol + water repellent[3]	2.0	1.8	3.2	4.3	4.8	0	20	80	100
3% pentachororphenol	2.2	.0	1.3	3.1	3.9	0	0	0	60
3% pentachlorophenol + water repellent[3]	2.1	.2	2.3	3.3	3.4	0	0	0	20
5% pentachlorophenol + water repellent[3]	2.1	.0	.3	2.2	2.4	0	0	0	0
Untreated	---	3.0	4.1	4.8	5.0	0	70	100	100
Water repellent, regular strength[4]	2.0	1.0	1.5	3.4	3.9	0	0	30	60
Water repellent, double strength[5]	2.0	.1	.8	2.8	3.5	0	0	0	10

	Solution absorbed lb./cu. ft.	Average decay rating[1] 2.7 yr.	3.4 yr.	4.4 yr.	Proportion of failure[2] 2.7 yr.	3.4 yr.	4.4 yr.
					Per cent		
5% sodium pentachlorophenate	1.5	2.3	3.1	3.8	0	10	40
5% sodium pentachlorophenate + water repellent[6]	1.5	1.4	2.8	3.7	0	0	30
5% sodium pentachlorophenate + water repellent[7]	1.2	1.2	2.0	3.7	0	0	40
Untreated	---	3.6	4.6	5.0	55	95	100

[1]Ratings on a basis of 0 (none) to 5 (destroyed).
[2]Percentage of boxes in decay classes 4 and 5.
[3]8% hydrogenated methyl ester of resin plus 2% paraffin wax was used as a water repellent.
[4]A commercial product that leaves paintable surfaces.
[5]A commercial product that interferes with subsequent painting.
[6]1% silicone (GE silicone SC-50).
[7]4% paraffin wax (8% Ceremul A).

Table 14.—EFFECT OF 2 COATS OF PAINT (TT–E–485b) ON THE EFFECTIVENESS OF 3 PRESERVATIVES IN PREVENTING DECAY IN SIMULATED BOXES OF SOUTHERN PINE SAPWOOD

Treatment	Absorption lb./cu. ft. Painted	Unpainted	Average decay rating[1] Painted 2.8 yr.	3.5 yr.	4.6 yr.	Unpainted 2.8 yr.	3.5 yr.	4.6 yr.	Proportion of failure[2] Painted 2.8 yr.	3.5 yr.	4.6 yr.	Unpainted 2.8 yr.	3.5 yr.	4.6 yr.
									Per cent					
3% pentachlorophenol	2.3	2.1	0.4	1.0	2.6	1.2	2.6	3.0	0	0	0	0	0	0
5% pentachlorophenol	2.2	2.3	.0	.1	1.8	2.0	2.5	2.6	0	0	0	0	0	0
Copper naphthenate, 0.6% Cu	2.1	1.9	.0	.1	1.9	1.9	2.7	3.5	0	0	0	0	40	50
Copper naphthenate, 1% Cu	1.8	1.9	.0	.1	.1	.1	.1	1.5	0	0	0	0	0	0
.18% copper 8-quinolinolate	1.8	1.9	.8	2.1	3.8	2.5	4.1	4.2	0	10	50	0	60	70
.3% copper 8-quinolinolate	2.0	1.8	.4	1.3	3.5	2.3	3.9	4.1	0	0	50	0	40	60
Untreated	---	---	---	---	---	3.3	4.2	5.0	---	---	---	40	67	100
Average (treated)	---	---	.3	.8	2.3	1.7	2.5	3.2	0	0.2	17	0	23	30

[1]Ratings on a basis of 0 (none) to 5 (destroyed).
[2]Percentage of boxes in decay classes 4 and 5.

Table 16.—AMOUNT OF METAL CORROSION ON M–22 BOXES EXPOSED FOR 38 MONTHS IN UNCOVERED PILES IN SOUTHERN MISSISSIPPI

Treatment	Proportion of boxes in each corrosion class[1]																			
	U-bolts										Strapping									
	With water repellent					Without water repellent					With water repellent					Without water repellent				
	0–1	2	3	4	5	0–1	2	3	4	5	0–1	2	3	4	5	0–1	2	3	4	5
	Per cent										Per cent									
Oil Solutions, 3-Minute Dips																				
Copper naphthenate																				
0.5% Cu	67	17	17	0	0	--	--	--	--	--	58	17	25	0	0	--	--	--	--	--
1.0% Cu	75	25	0	0	0	67	33	0	0	0	33	67	0	0	0	50	25	25	0	0
2.0% Cu	83	17	0	0	0	75	25	0	0	0	58	42	0	0	0	33	42	25	0	0
Copper pentachlorophenate																				
2.5%	58	25	8	8	0	--	--	--	--	--	33	33	17	8	8	--	--	--	--	--
5.0%	42	50	8	0	0	0	42	50	8	0	17	33	25	25	0	0	33	33	33	0
Copper 3-phenyl salicylate																				
1.25%	67	33	0	0	0	--	--	--	--	--	8	67	25	0	0	--	--	--	--	--
2.5%	25	75	0	0	0	17	75	8	0	0	25	75	0	0	0	17	75	8	0	0
5.0%	42	50	8	0	0	0	25	67	8	0	17	58	25	0	0	8	50	42	0	0
Copper 8-quinolinolate																				
0.15%	58	33	8	0	0	--	--	--	--	--	8	67	25	0	0	--	--	--	--	--
0.3%	33	58	8	0	0	8	50	42	0	0	17	83	0	0	0	0	75	25	0	0
0.6%	50	50	0	0	0	0	67	25	8	0	17	58	25	0	0	0	67	25	8	0
0.3% plus 0.5% gamma benzene hexachloride	--	--	--	--	--	0	83	17	0	0	--	--	--	--	--	0	83	17	0	0
Mineral spirits (aliphatic)	21	79	0	0	0	33	58	8	0	0	37	64	0	0	0	17	83	0	0	0
Orthophenylphenol																				
2.5%	25	58	17	0	0	--	--	--	--	--	17	50	33	0	0	--	--	--	--	--
5.0%	25	58	17	0	0	0	83	17	0	0	8	42	33	17	0	25	67	8	0	0
10.0%	58	42	0	0	0	8	42	50	0	0	25	58	0	17	0	0	25	75	0	0
Pentachlorophenol																				
2.5%	33	50	17	0	0	--	--	--	--	--	17	67	17	0	0	--	--	--	--	--
5.0%	75	25	0	0	0	30	40	30	0	0	58	42	0	0	0	40	50	10	0	0
10.0%	54	27	18	0	0	42	50	8	0	0	36	36	27	0	0	50	42	8	0	0
5.0% plus 0.5% gamma benzene hexachloride	--	--	--	--	--	8	83	8	0	0	--	--	--	--	--	8	50	42	0	0
Phenyl mercuric oleate																				
0.15%	42	58	0	0	0	--	--	--	--	--	42	50	8	0	0	--	--	--	--	--
0.3%	8	75	17	0	0	17	58	25	0	0	8	50	42	0	0	25	67	8	0	0
0.6%	42	42	17	0	0	8	58	33	0	0	25	67	8	0	0	0	92	0	8	0
Product containing 23% zinc naphthenate, 2.5% (coco) dodecyl-amine salt of tetrachlorophenol, and 28.5% water repellent																				
25.0%	50	25	25	0	0	--	--	--	--	--	50	25	25	0	0	--	--	--	--	--
37.5%	33	67	0	0	0	--	--	--	--	--	17	83	0	0	0	--	--	--	--	--
Rosin amine D pentachlorophenate																				
2.75%	58	42	0	0	0	--	--	--	--	--	8	92	0	0	0	--	--	--	--	--
5.5%	25	58	17	0	0	25	75	0	0	0	17	67	17	0	0	8	67	25	0	0
11.0%	67	33	0	0	0	8	58	25	8	0	42	58	0	0	0	17	58	17	8	0
Tetrachlorophenol																				
2.5%	33	33	33	0	0	--	--	--	--	--	33	33	33	0	0	--	--	--	--	--
5.0%	42	50	8	0	0	8	25	50	17	0	17	75	8	0	0	58	17	17	8	0
10.0%	42	33	25	0	0	33	42	25	0	0	25	50	25	0	0	0	42	33	25	0
Zinc alkyl sulphonate																				
2.8%	0	75	25	0	0	--	--	--	--	--	0	83	17	0	0	--	--	--	--	--
5.7%	33	58	8	0	0	--	--	--	--	--	8	92	0	0	0	--	--	--	--	--
Zinc naphthenate																				
0.5% Zn	25	75	0	0	0	--	--	--	--	--	33	67	0	0	0	--	--	--	--	--
1.0% Zn	67	33	0	0	0	42	33	25	0	0	50	50	0	0	0	42	50	8	0	0
2.0% Zn	75	25	0	0	0	25	67	8	0	0	17	83	0	0	0	42	42	17	0	0
Water Solutions, 3-Minute Dips																				
Copper ammonium fluoride																				
5.0%	--	--	--	--	--	0	0	0	92	8	--	--	--	--	--	0	0	8	58	33
10.0%	0	0	0	42	58	0	0	0	33	67	0	0	0	25	75	0	0	0	8	92
20.0%	--	--	--	--	--	0	0	0	17	83	--	--	--	--	--	0	0	0	8	92
Product containing sodium salts of dimethyl dithiocarbamic acid, 2-mercapto benzothiazole and pentachlorophenol																				
2.5%	--	--	--	--	--	17	42	42	0	0	--	--	--	--	--	0	42	50	0	8
7.5%	--	--	--	--	--	0	17	58	25	0	--	--	--	--	--	0	0	17	8	75
Rosin amine D acetate																				
2.5%	--	--	--	--	--	8	83	8	0	0	--	--	--	--	--	17	67	17	0	0
5.0%	--	--	--	--	--	25	33	42	0	0	--	--	--	--	--	0	75	25	0	0
10.0%	--	--	--	--	--	0	42	58	0	0	--	--	--	--	--	0	33	67	0	0
Sodium pentachlorophenate																				
2.85%	--	--	--	--	--	8	25	58	8	0	--	--	--	--	--	0	42	58	0	0
5.7%	21	42	30	8	0	17	42	42	0	0	0	42	42	8	8	0	17	83	0	0
11.4%	--	--	--	--	--	8	67	25	0	0	--	--	--	--	--	0	75	25	0	0
2.0% plus borax 3.0%	25	67	8	0	0	17	25	50	8	0	50	42	8	0	0	0	58	33	8	0
4.0% plus borax 4.0%	--	--	--	--	--	8	8	75	8	0	--	--	--	--	--	0	33	50	17	0
Sodium tetrachlorophenate																				
2.85%	42	25	25	8	0	--	--	--	--	--	42	17	33	0	8	--	--	--	--	--
5.7%	33	33	8	25	0	8	17	75	0	0	33	25	25	17	0	0	17	42	33	8
Water repellent, 4% solids	8	92	0	0	0	--	--	--	--	--	17	50	33	0	0	--	--	--	--	--
Oil Solution, Pressure Treatment																				
Pentachlorophenol	67	25	8	0	0	8	58	33	0	0	42	58	0	0	0	0	50	50	0	0
Water Solutions, Pressure Treatments																				
Copperized chromated zinc chloride	--	--	--	--	--	0	33	33	33	0	--	--	--	--	--	0	0	0	56	44
Celcure	--	--	--	--	--	0	0	78	22	0	--	--	--	--	--	0	0	22	56	22
Tanalith	--	--	--	--	--	0	56	44	0	0	--	--	--	--	--	0	67	33	0	0
Untreated																				
	15	63	23	0	0	--	--	--	--	--	6	58	35	0	0	--	--	--	--	--

[1] Ratings on a basis of 0 (none) to 5 (destroyed).

Several treatments resulted in significantly less strap corrosion than occurred on the untreated controls. Zinc naphthenate at all concentrations tested and with or without water repellent resulted in significantly less (.6 to .7 as much) corrosion of strapping than occurred on the untreated boxes. Corrosion of U-bolts also was less than on the untreated boxes, but the differences were not so great as with the strapping. Boxes treated with copper naphthenate also usually had less strap corrosion than the controls, but not so consistently as those treated with zinc naphthenate.

Metal corrosion was significantly less on boxes in the pile covered with the tarpaulin (Table 18). Here only the hardware on boxes treated with copper ammonium fluoride was seriously corroded, and then to a lesser degree than on uncovered boxes.

The effect of painting on the corrosion rate of strapping is summarized in Table 19. The outer face of the strapping was painted as well as the wood surfaces. This materially reduced the amount of corrosion, as the following averages show:

Treatment	Unpainted	Painted
11 oil treatments with WR	1.8	1.2
4 water treatments without WR (excluding copper ammonium fluoride)	2.7	1.6
Untreated	2.3	1.3

The addition of a water repellent to oil solutions reduced corrosion of both U-bolts and strapping in Mississippi (Table 16). This was true of 17 of 21 comparisons for U-bolts and 16 of 21 comparisons for strapping. The average rating for U-bolts was reduced from 2.0 to 1.5 and strapping from 2.1 to 1.8. With water solutions (excluding copper ammonium fluoride), there were three comparisons. The addition of the water repellent reduced corrosion of U-bolts in each case—the average rating being reduced from 2.5 to 2.0—but had no effect on average corrosion ratings for strapping. In the Panama exposures there were only 2 comparisons with water treatments, and 1 with oil. In all 3 comparisons, the water repellent caused more corrosion of strapping, and in 2 of the 3 more corrosion of U-bolts. Because of the small number of comparisons in Panama, however, there is no assurance that this apparent reversal would apply in general.

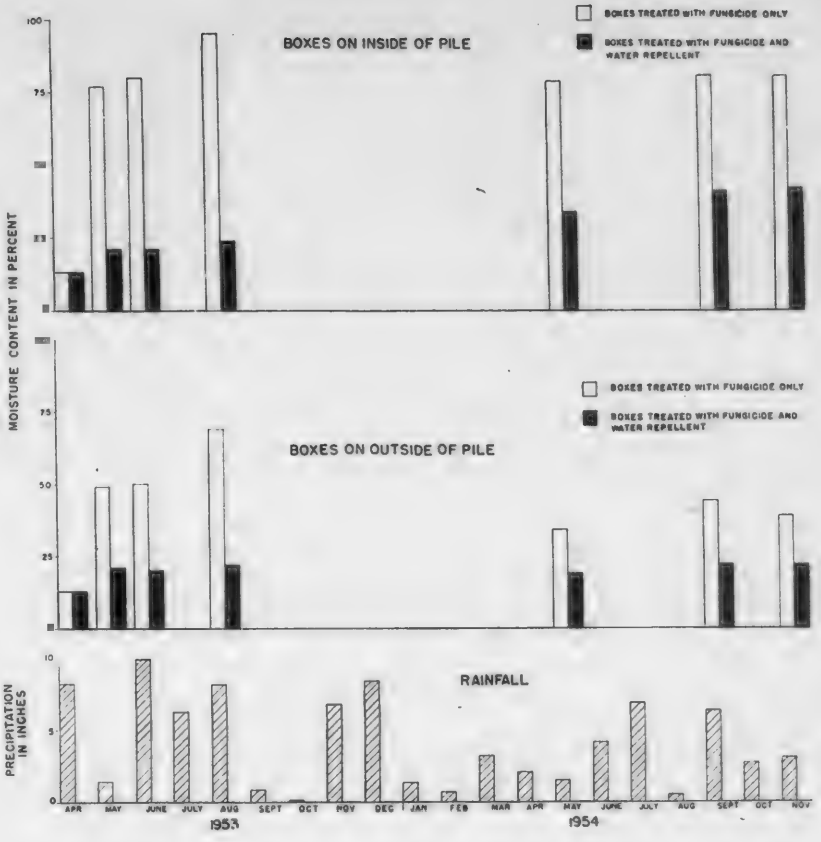

BOXES TREATED WITH FUNGICIDE ONLY
BOXES TREATED WITH FUNGICIDE AND WATER REPELLENT
BOXES ON INSIDE OF PILE
MOISTURE CONTENT IN PERCENT
BOXES ON OUTSIDE OF PILE
RAINFALL
PRECIPITATION IN INCHES
APR MAY JUNE JULY AUG SEPT OCT NOV DEC JAN FEB MAR APR MAY JUNE JULY AUG SEPT OCT NOV
1953
1954

Fig. 6.—The effectiveness of a water repellent applied as a 3-minute dip in preventing wetting of M22 boxes by rainwater. Exposure was in Mississippi. Fungicide was pentachlorophenol.

Table 15.—RELATIVE EFFECTIVENESS OF PRESERVATIVES APPLIED TO SOUTHERN PINE SAPWOOD SIMULATED BOXES IN MINERAL SPIRITS AND A NUMBER 2 FUEL OIL WHEN USED AS A 3-MINUTE DIP

Treatment	Solution absorbed lb./cu.ft.	Average decay rating[1] 1.6 yr.	2.9 yr.	3.4 yr.	4.5 yr.	Proportion of failure[2] 1.6 yr.	2.9 yr.	3.4 yr.	4.5 yr.
						Percent			
Copper naphthenate, 1% Cu									
Mineral spirits	1.8	0.0	0.1	0.9	2.2	0	0	0	0
Fuel oil	2.1	.0	.3	1.3	1.8	0	0	0	0
0.3% copper 8-quinolinolate									
Mineral spirits	1.6	.0	1.0	2.0	3.4	0	0	0	20
Fuel oil	1.8	.0	1.1	2.5	2.6	0	0	0	0
5% orthophenylphenol									
Mineral spirits	1.9	1.5	1.9	2.7	3.6	0	0	0	50
Fuel oil	2.2	.0	.1	2.2	3.1	0	0	20	20
5% pentachlorophenol									
Mineral spirits	2.0	.0	.0	.9	2.3	0	0	0	0
Fuel oil	1.9	.0	.0	1.2	2.3	0	0	0	0
Untreated	---	2.9	3.3	4.2	5.0	0	40	68	100

[1] Ratings on a basis of 0 (none) to 5 (destroyed).
[2] Percentage of boxes in decay classes 4 and 5.

Insect Attack

The only insect importantly attacking sound boxes in Mississippi was the subterranean termite *Reticulitermes*. Borers, however, did commonly enter decayed wood. In Panama the greatest damage was by the subterranean termite *Coptotermes niger*, but some damage was caused by the termites *Nasutitermes* and *Heterotermes*. In Panama practically all treatments except the inorganic salts applied by pressure were commonly penetrated by an unidentified borer, but the resulting damage was insignificant.

Termite attack was rated on a scale of 0 to 5:

0	No attack
1	Nibbles, but no penetration
2	Penetration, but limited damage
3	Attack general, but only minor loss in strength
4	Heavy attack; box would fail in drop test
5	Destroyed

Termite attack in Mississippi was much slower than decay attack (Tables 20 and 3). Even with the untreated boxes, damage was restricted to the bottom units in contact with the soil. In Mississippi, pressure treatments with Celcure, Tanalith, and copperized chromated zinc chloride prevented termite damage for 5 years. Similar treatment with pentachlorophenol permitted slight attack, but no important damage.

Dip treatments, because they result only in a surface covering of the toxicant, are less effective against termites

Table 17.—AMOUNT OF METAL CORROSION ON M-22 BOXES EXPOSED FOR 42 MONTHS IN UNCOVERED[1] PILES IN THE PANAMA CANAL ZONE

Treatment	Proportion of boxes in each corrosion class[2]: U-bolts 0–1	2	3	4	5	Strapping 0–1	2	3	4	5
	Per cent									
Oil Solutions, 3-Minute Dips										
Benzene hexachloride, (0.5% gamma)	0	22	78	0	0	0	78	22	0	0
Copper naphthenate, (1% Cu) plus WR	11	78	11	0	0	0	89	11	0	0
Copper naphthenate, (2% Cu) plus WR	44	44	11	0	0	0	78	22	0	0
Copper pentachlorophenate, 5% plus WR	0	0	56	44	0	0	56	11	33	0
Copper 3-phenyl salicylate, 2.5% plus WR	17	33	50	0	0	6	50	44	0	0
Copper 3-phenyl salicylate, 5.0% plus WR	0	33	67	0	0	0	56	44	0	0
Copper 8-quinolinolate, 0.3% plus WR	11	67	22	0	0	0	67	33	0	0
Copper 8-quinolinolate, 0.6% plus WR	0	67	33	0	0	0	67	33	0	0
Copper 8-quinolinolate, 0.3%, plus 0.5% gamma benzene hexachloride	0	0	100	0	0	0	67	33	0	0
Orthophenylphenol, 5% plus WR	0	67	33	0	0	0	33	67	0	0
Orthophenylphenol, 10% plus WR	0	67	22	11	0	0	67	22	11	0
Pentachlorophenol, 5% plus WR	0	25	38	38	0	0	63	38	0	0
Pentachlorophenol, 10% plus WR	0	22	56	22	0	0	11	89	0	0
Pentachlorophenol, 5% plus 0.5% gamma benzene hexachloride	0	22	67	11	0	0	44	56	0	0
Phenyl mercuric oleate, 0.3% plus WR	0	56	44	0	0	0	67	33	0	0
Phenyl mercuric oleate, 0.6% plus WR	0	33	56	11	0	0	22	78	0	0
Product containing 23% zinc naphthenate, 2.5% (coco) dodecyl-amine salt of tetrachlorophenol, and 28.5% water repellent 25.0%	0	100	0	0	0	0	78	22	0	0
37.5%	0	89	11	0	0	11	67	22	0	0
Rosin amine D pentachlorophenate, 5.5% plus WR	0	11	78	11	0	0	44	56	0	0
Rosin amine D pentachlorophenate, 11.0% plus WR	0	33	44	22	0	0	56	33	11	0
Tetrachlorophenol, 5% plus WR	0	22	67	11	0	11	11	67	11	0
Tetrachlorophenol, 10% plus WR	0	33	56	11	0	0	56	33	11	0
Water repellent only	6	47	47	0	0	6	53	41	0	0
Zinc alkyl sulphonate, 5.7% plus WR	0	33	67	0	0	11	44	44	0	0
Zinc naphthenate, (1% Zn) plus WR	67	33	0	0	0	44	44	11	0	0
Zinc naphthenate, (2% Zn) plus WR	78	22	0	0	0	67	33	0	0	0
Water Solutions, 3-Minute Dips										
Copper ammonium fluoride, 10%	0	0	0	100	0	0	0	0	100	0
Copper ammonium fluoride, 20%	0	0	0	75	25	0	0	13	62	25
Copper ammonium fluoride, 10% plus WR	0	0	0	33	67	0	0	0	33	67
Product containing sodium salts of dimethyl dithiocarbamic acid and 2-mercapto benzothiazole, and pentachlorophenol, 7.5%	0	0	89	11	0	0	0	89	11	0
Rosin amine D acetate, 5%	0	44	56	0	0	0	78	22	0	0
Rosin amine D acetate, 10%	0	33	67	0	0	0	78	22	0	0
Sodium pentachlorophenate, 5.7%	0	11	33	56	0	0	33	56	11	0
Sodium pentachlorophenate, 11.4%	0	0	44	56	0	0	11	56	33	0
Sodium pentachlorophenate, 2.0%, plus borax 3%	0	11	78	11	0	0	0	100	0	0
Sodium pentachlorophenate, 4.0%, plus borax 4%	11	11	44	33	0	0	33	67	0	0
Sodium pentachlorophenate, 2.0%, plus borax 3%, plus WR	0	0	22	78	0	0	11	33	56	0
Sodium tetrachlorophenate, 5.7%	0	0	67	33	0	0	0	100	0	0
Sodium tetrachlorophenate, 5.7% plus WR	0	11	0	89	0	0	0	22	78	0
Oil Solutions, Pressure Treatments										
Pentachlorophenol, 5%	0	11	78	11	0	0	56	44	0	0
Pentachlorophenol, 5% plus WR	0	11	78	11	0	0	22	67	11	0
Water Solutions, Pressure Treatments										
Copperized chromated zinc chloride	0	0	0	100	0	0	0	0	33	67
Tanalith	33	33	33	0	0	0	67	33	0	0
Celcure	0	0	17	83	0	0	0	17	83	0
Untreated	0	59	29	12	0	0	53	41	6	0

[1]One of 3 piles was covered after 18 months. The boxes remained moist, but not wet.
[2]Rated on a basis of 0 (none) to 5 (destroyed).

than against decay. Termites attack by chewing away the treated surface. Many may be poisoned before a passageway is eaten into the untreated interior, but many will remain to continue the attack once the treated shell is broken. Among the 3-minute dips, attack was appreciably reduced only by 0.3 per cent copper 8-quinolinolate plus 0.5 per cent gamma benzene hexachloride, 5 per cent pentachlorophenol plus 0.5 per cent gamma benzene hexachloride, and 10 per cent rosin amine D pentachlorophenate. Benzene hexachloride, which is a good insecticide, was added to these two fungicides in the hope that it would increase resistance to termites, but the protection gained was not so great as that afforded by soil treatment.

In Panama, termite attack was very rapid on boxes exposed on untreated soil (Table 21), and attacked boxes were usually destroyed in 6 months. This was much faster than decay action. After the first half year, however, very few failures from termites were recorded, and very little activity was noted except when piles were disturbed in examination. Perhaps high moisture content of the wood reduced termite attack as well as typical decay.

Only the pressure treatments with Tanalith and copperized chromated zinc chloride and a 3-minute dip in 10 per cent orthophenylphenol prevented serious termite attack in Panama for 2.5 years. Eight other treatments, however, showed some effectiveness in that heavy attack was restricted to the bottom boxes in contact with the soil:

Copper naphthenate (2% Cu) plus WR	3-minute dip
Copper pentachlorophenate, 5% plus WR	3-minute dip
Copper 8-quinolinolate, 0.3% plus WR	3-minute dip
Pentachlorophenol, 5% plus 0.5% gamma benzene hexachloride	3-minute dip
Pentachlorophenol, 10% plus WR	3-minute dip
Sodium pentachlorophenate, 4% plus borax, 4%	3-minute dip
Sodium tetrachlorophenate, 5.7%	3-minute dip
Pentachlorophenol plus WR	pressure

Table 18.—EFFECT OF TARPAULIN COVER ON THE AMOUNT OF METAL CORROSION ON M–22 BOXES EXPOSED FOR 38 MONTHS IN SOUTH MISSISSIPPI

Treatment	Proportion of boxes with U-bolts in each corrosion class[1]: Covered pile 0–1	2	3	4	5	Uncovered piles 0–1	2	3	4	5	Proportion of boxes with strapping in each corrosion class[1]: Covered pile 0–1	2	3	4	5	Uncovered piles 0–1	2	3	4	5
	Per cent																			
Oil Solutions, 3-Minute Dips																				
Copper naphthenate (1% Cu) plus WR	100	0	0	0	0	75	25	0	0	0	100	0	0	0	0	33	67	0	0	0
Copper 3-phenyl salicylate, 2.5% plus WR	100	0	0	0	0	25	75	0	0	0	100	0	0	0	0	25	75	0	0	0
Copper 8-quinolinolate, 0.3% plus WR	100	0	0	0	0	33	58	8	0	0	100	0	0	0	0	17	83	0	0	0
Mineral spirits (aliphatic) 100%	50	50	0	0	0	33	58	8	0	0	100	0	0	0	0	17	83	0	0	0
Mineral spirits (aliphatic) 100%, plus WR	100	0	0	0	0	21	79	0	0	0	100	0	0	0	0	37	64	0	0	0
Orthophenylphenol, 5% plus WR	100	0	0	0	0	25	58	17	0	0	100	0	0	0	0	8	42	33	17	0
Pentachlorophenol, 5% plus WR	100	0	0	0	0	75	25	0	0	0	100	0	0	0	0	58	42	0	0	0
Phenyl mercuric oleate, 0.3% plus WR	83	17	0	0	0	8	75	17	0	0	100	0	0	0	0	8	50	42	0	0
Rosin amine D pentachlorophenate, 5.5% plus WR	100	0	0	0	0	25	58	17	0	0	100	0	0	0	0	17	67	17	0	0
Zinc naphthenate, (1% Zn) plus WR	100	0	0	0	0	67	33	0	0	0	100	0	0	0	0	50	50	0	0	0
Water Solutions, 3-Minute Dips																				
Copper ammonium fluoride, 10%	0	0	92	8	0	0	0	0	33	67	0	0	0	100	0	0	0	0	8	92
Sodium pentachlorophenate, 2%, plus borax, 3.0%	33	67	0	0	0	17	25	50	8	0	75	25	0	0	0	0	58	33	8	0
Water Solutions, Pressure Treatments																				
Copperized chromated zinc chloride	67	33	0	0	0	0	33	33	33	0	11	78	11	0	0	0	0	0	56	44
Tanalith	22	67	11	0	0	0	56	44	0	0	0	89	11	0	0	0	67	33	0	0
Celcure	78	22	0	0	0	0	0	78	22	0	22	78	0	0	0	0	0	22	56	22
Untreated	67	33	0	0	0	15	63	23	0	0	100	0	0	0	0	6	58	35	0	0

[1]Ratings on a basis of 0 (none) to 5 (destroyed).

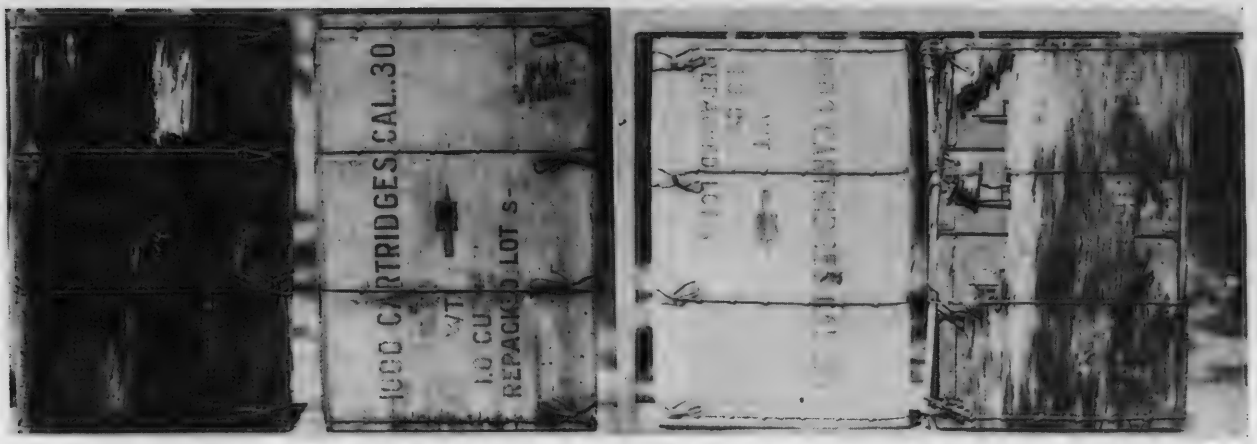


Fig. 7.—Rotary-cut hardwood veneer crates exposed in uncovered piles in Mississippi. (Left) After 1.3 years' exposure: heavy stain and important decay in untreated crate. Crate given a 3-minute dip in 5 per cent pentachlorophenol plus a water repellent is essentially free of stain and decay. (Right) Similar boxes after 3.1 years exposure.

In Wisconsin, no termite attack occurred.

Some boxes exposed in Mississippi had two spray coats of paint (TT-E-485b). Painting reduced termite attack in both treated and untreated boxes (Table 22). Only one painted box failed, as compared with 16 of the comparable unpainted boxes. It is doubtful, however, that painting should be considered an important termite-prevention measure. In Panama, where the voracious *Coptotermes* is common, painting would probably have had little effect.

Two piles in Mississippi and one pile in Panama were on soil that had been poisoned with DDT. Two additional piles in Panama were on a concrete slab that had been similarly poisoned. No termite attack occurred in the Mississippi piles on treated soil for four years. During the fifth year, a few termites entered one corner of the pile, but had not caused any damage. In Panama, *Nasutitermes* bridged into two treated piles through fallen branches and destroyed some boxes. No attack, however, occurred through the treated soil during 4.5 years.

Table 19.—EFFECT OF 2 COATS OF PAINT (TT-E-485b) ON THE AMOUNT OF CORROSION OF GALVANIZED STRAPPING ON M-22 BOXES TREATED WITH VARIOUS PRESERVATIVES AND EXPOSED WITHOUT COVER FOR 38 MONTHS IN SOUTH MISSISSIPPI

Treatment	Proportion of boxes in each corrosion class[1]									
	Painted					Unpainted				
	0–1	2	3	4	5	1	2	3	4	5
	Per cent									
Oil Solutions, 3-Minute Dips										
Copper naphthenate, (1% Cu) plus WR	83	17	0	0	0	33	67	0	0	0
Copper 3-phenyl salicylate, 2.5% plus WR	67	33	0	0	0	25	75	0	0	0
Copper 8-quinolinolate, 0.3% plus WR	50	50	0	0	0	17	83	0	0	0
Mineral spirits (aliphatic) 100%	100	0	0	0	0	17	83	0	0	0
Mineral spirits (aliphatic) 100%, plus WR	96	4	0	0	0	37	64	0	0	0
Orthophenylphenol, 5% plus WR	58	33	8	0	0	8	42	33	17	0
Pentachlorophenol, 5% plus WR	58	42	0	0	0	58	42	0	0	0
Phenyl mercuric oleate, 0.3% plus WR	100	0	0	0	0	8	50	42	0	0
Product containing 23% zinc naphthenate, 2.5% (coco) dodecyl-amine salt of tetrachlorophenol, and 28.5% water repellent 37.5%	100	0	0	0	0	17	83	0	0	0
Rosin amine D pentachlorophenate, 5.5% plus WR	42	58	0	0	0	17	67	17	0	0
Zinc alkyl sulphonate, 5.7% plus WR	50	17	33	0	0	0	83	17	0	0
Zinc naphthenate, (1% Zn) plus WR	92	8	0	0	0	50	50	0	0	0
Water Solutions, 3-Minute Dips										
Copper ammonium fluoride, 10%	0	0	0	25	75	0	0	0	8	92
Rosin amine D acetate, 5%	75	25	0	0	0	0	75	25	0	0
Sodium pentachlorophenate, 5.7%	42	58	0	0	0	0	17	83	0	0
Sodium pentachlorophenate, 2.0% plus borax 3.0%	58	25	0	17	0	0	58	33	8	0
Sodium tetrachlorophenate, 5.7%	42	42	8	0	8	0	17	42	33	8
Oil Solution, Pressure Treatment										
Pentachlorophenol, 5%	58	42	0	0	0	0	50	50	0	0
Untreated	79	17	4	0	0	6	58	35	0	0

[1] Ratings on a basis of 0 (none) to 5 (destroyed).

Water Repellency

Test units exposed in Mississippi were weighed periodically to determine how much rain-wetting had occurred. Weights were also secured once in Panama and Wisconsin, but unless otherwise stated, weights are for Mississippi. Fully air-dried boxes weighed 7 to 10 pounds, with an average weight of about 8 pounds. In general, boxes in the 12 to 15 pound range were optimum for decay. Those at 18 to 20 pounds were probably at or near the maximum moisture content for decay, and those below 10 pounds contained too little moisture for decay. It must be remembered that these relationships are average. For example, a box may weigh 10 pounds and still have individual boards sufficiently wet to be decayed.

In wet periods, the boxes under cover became moist where in contact with the soil but no traces of condensation were found in this test. The boxes should remain too dry to decay as long as the tarpaulin is water-tight, or except for wetting by the rare water-conducting fungus (Fig. 2B).

A tarpaulin cover (Fig. 1) kept boxes dry during the entire 5-year exposure period, as the following average weights show:

Exposure condition	Average weight per box (lbs.)		
	Oil solutions		Water solutions
	No WR	WR	No WR
Under tarpaulin			
Outside and inside tiers	8.1	8.0	8.1
Fully exposed			
Outside tiers	8.9	8.7	8.8
Inside tiers	13.6	11.8	13.1

Two spray coats of paint (TT–E–485b, Type II) had some effect on moisture content. Boxes treated with copper naphthenate (2 per cent Cu) and 5 per cent pentachlorophenol, when weighed during a dry period in May and a wet period in August 1954, had the following weights:

Treatment	Average weight (lb.) of boxes in inside tiers			
	Dry weather		Wet weather	
	Painted	Unpainted	Painted	Unpainted
With water repellent	9.7	9.5	10.0	9.8
Without water repellent	11.8	12.9	11.8	13.3
Untreated	12.1	14.8	12.3	17.3

Paint reduced wetting, but without the water repellent the reduction was not sufficient to keep the moisture content below the minimum for decay activity. As pointed out earlier, however, the paint did reduce the amount of decay.

Next to the tarpaulin cover, water repellents had the most marked effect on moisture content of boxes. The average effect of all water-repellent treatments at Gulfport is shown in Fig. 6. For this graph, weights were transformed to moisture contents expressed as percentage of oven-dry weight. There is no doubt that the addition of a water repellent reduced water absorption. The effect was very striking for exposures of a few months, but with prolonged storage, water-repellent-treated boxes became and remained sufficiently wet inside test piles to support optimum decay. This water accumulation was particularly evident in Panama where, after 18 months, boxes given water-repellent treatment averaged 18.2 pounds for inside tiers and 14.2 pounds for outside tiers. Many of the boxes weighed 20 pounds and were probably at the maximum moisture content for ordinary types of decay.

The water repellents were effective on all wood species tested (Table 23). Units made of less permeable woods, such as the heartwood of southern pine and Douglas-fir, when treated, showed appreciably slower water build-up than did the more permeable woods. This factor, along with moderate natural decay resistance, probably contributes importantly to the apparently better protection afforded by dip treatments to some wood species.

Repellents applied as 3-minute dips prevented moisture pickup as effectively as when aplied by pressure. The following weights were secured after a wet period (18 months' exposure):

	Average weight (lbs.) of boxes in inside tiers
5% pentachlorophenol plus WR	
3-minute dip	9.3
Pressure treatment	9.6
5% pentachlorophenol (no WR)	13.8

In supplementary tests, a 5-second dip was just as effective as a 10-minute soak in imparting water repellency (Tables 24 and 25).

Water repellent WR-7 was effective in overcoming the high absorbency of wood molded with *Trichoderma* (8). Matched boards of southern pine sapwood, some of which were intentionally molded with *Trichoderma,* were given 3-minute dips. The amount of preservative absorbed and average moisture content at different exposure periods are listed in Table 26. The 3-minute dip resulted in excessive ab-

Table 20.—SUBTERRANEAN TERMITE ATTACK ON M-22 BOXES EXPOSED FOR 38 MONTHS ON NON-POISONED SOIL IN SOUTHERN MISSISSIPPI

Treatment	Proportion of boxes in each rating class[1]									
	With water repellent					Without water repellent				
	0–1	2	3	4	5	0–1	2	3	4	5
	Per cent									
Oil Solutions, 3-Minute Dips										
Copper naphthenate, 0.5% Cu	75	0	25	0	0	--	--	--	--	--
Copper naphthenate, 1.0% Cu	75	0	25	0	0	88	13	0	0	0
Copper naphthenate, 2.0% Cu	75	25	0	0	0	75	0	25	0	0
Copper pentachlorophenate, 2.5%	88	13	0	0	0	--	--	--	--	--
Copper pentachlorophenate, 5.0%	75	13	13	0	0	88	0	13	0	0
Copper 3-phenyl salicylate, 1.25%	75	0	13	13	0	--	--	--	--	--
Copper 3-phenyl salicylate, 2.5%	75	0	25	0	0	75	0	13	13	0
Copper 3-phenyl salicylate, 5.0%	75	13	13	0	0	75	0	25	0	0
Copper 8-quinolinolate, 0.15%	75	0	25	0	0	--	--	--	--	--
Copper 8-quinolinolate, 0.3%	75	0	0	25	0	75	0	0	25	0
Copper 8-quinolinolate, 0.6%	75	13	0	0	13	75	0	25	0	0
Copper 8-quinolinolate, 0.3% plus 0.5% gamma benzene hexachloride	--	--	--	--	--	88	13	0	0	0
Mineral spirits (aliphatic)	75	0	19	6	0	75	0	13	0	13
Orthophenylphenol, 2.5%	75	0	25	0	0	--	--	--	--	--
Orthophenylphenol, 5.0%	75	0	25	0	0	75	0	13	13	0
Orthophenylphenol, 10.0%	75	0	13	13	0	75	0	25	0	0
Pentachlorophenol, 2.5%	75	0	13	13	0	--	--	--	--	--
Pentachlorophenol, 5.0%	75	0	13	13	0	75	0	25	0	0
Pentachlorophenol, 10.0%	75	0	25	0	0	75	0	25	0	0
Pentachlorophenol, 5.0% plus 0.5% gamma benzene hexachloride	--	--	--	--	--	75	25	0	0	0
Phenyl mercuric oleate, 0.15%	75	0	13	0	13	--	--	--	--	--
Phenyl mercuric oleate, 0.3%	75	0	13	13	0	75	0	0	25	0
Phenyl mercuric oleate, 0.6%	75	13	13	0	0	75	0	13	13	0
Product containing 23% zinc naphthenate, 2.5% (coco) dodecyl amine salt of tetrachlorophenol, and 25.5% water repellent										
25.0%	75	0	13	0	13	--	--		--	--
37.5%	75	0	25	0	0	--	--	--	--	--
Rosin amine D pentachlorophenate, 2.75%	75	0	13	13	0	--	--	--	--	--
Rosin amine D pentachlorophenate, 5.5%	75	0	13	13	0	75	0	13	13	0
Rosin amine D pentachlorophenate, 11.0%	75	0	25	0	0	75	0	13	13	0
Tetrachlorophenol, 2.5%	75	13	0	13	0	--	--	--	--	--
Tetrachlorophenol, 5.0%	75	0	25	0	0	75	0	13	13	0
Tetrachlorophenol, 10.0%	75	13	13	0	0	75	0	25	0	0
Zinc alkyl sulphonate, 2.8%	75	0	25	0	0	--	--	--	--	--
Zinc alkyl sulphonate, 5.7%	75	0	0	25	0	--	--	--	--	--
Zinc naphthenate, 0.5% Zn	75	0	25	0	0	--	--	--	--	--
Zinc naphthenate, 1.0% Zn	75	0	0	25	0	75	0	13	13	0
Zinc naphthenate, 2.0% Zn	75	0	13	13	0	75	0	25	0	0
Water Solutions, 3-Minute Dips										
Copper ammonium fluoride, 5.0%	--	--	--	--	--	75	0	13	13	0
Copper ammonium fluoride, 10.0%	75	13	13	0	0	75	13	13	0	0
Copper ammonium fluoride, 20.0%	--	--	--	--	--	75	13	13	0	0
Product containing sodium salts of dimethyl dithiocarbamic acid, 2-mercapto benzothiazole and pentachlorophenol										
2.5%	--	--	--	--	--	75	0	13	0	13
7.5%	--	--	--	--	--	75	0	25	0	0
Rosin amine D acetate, 2.5%	--	--	--	--	--	75	0	13	0	13
Rosin amine D acetate, 5.0%	--	--	--	--	--	75	0	13	13	0
Rosin amine D acetate, 10.0%	--	--	--	--	--	88	13	0	0	0
Sodium pentachlororphenate, 2.85%	--	--	--	--	--	75	0	25	0	0
Sodium pentachlorophenate, 5.7%	75	0	19	6	0	75	0	25	0	0
Sodium pentachlorophenate, 11.4%	--	--	--	--	--	75	13	13	0	0
Sodium pentachlorophenate, 2.0% plus borax 3.0%	75	0	25	0	0	75	0	13	13	0
Sodium pentachlorophenate, 4.0% plus borax 4.0%	--	--	--	--	--	75	0	25	0	0
Sodium tetrachlorophenate, 2.85%	75	0	25	0	0	--	--	--	--	--
Sodium tetrachlorophenate, 5.7%	75	0	25	0	0	75	0	13	13	0
Water repellents, 4% solids	75	0	25	0	0	--	--	--	--	--
Oil Solution, Pressure Treatment										
Pentachlorophenol	75	0	25	0	0	88	0	13	0	0
Water Solutions, Pressure Treatments										
Copperized chromated zinc chloride	--	--	--	--	--	100	0	0	0	0
Celcure	--	--	--	--	--	100	0	0	0	0
Tanalith	--	--	--	--	--	100	0	0	0	0
Untreated	--	--	--	--	--	75	0	12	6	6

[1] Ratings on a basis of 0 (none) to 5 (destroyed).

sorption of the preservative by the molded wood. It is not known if absorptions by the molded wood comparable to those by the bright wood would have given good repellency.

Wood dipped in a water repellent without a toxicant had good repellency during early exposure, but lost it after 6 months to 1 year of exposure (Table 27). Presumably, molds developing on the wood increase its absorbency. Wood given a 3-minute dip in a commercial water repellent with high solids content (leaving non-paintable surfaces) maintained its effectiveness for two years, the longest period under test.

Small differences were found between various commercial water-repellent preservatives sold as meeting Federal Specification TT-W-572, but they were not of practical magnitude. None was superior to the WR-7 formula used in the main box test. Twenty per cent linseed oil was somewhat less effective and 12 per cent alkyd resins were very much less effective than WR-7 (Table 28). Four per cent wax in water emulsions was as effective as 2 per cent wax in oil solutions (Table 29). One per cent silicone in water solution was somewhat less effective than the wax emulsion (Table 29).

Miscellaneous Factors Influencing Box Treatments

The over-all deterioration rate in Panama (Table 6) was higher than in Mississippi, but still decay was slower than anticipated. To test the likelihood that the high rainfall maintained wood moisture contents near the maximum for decay, one of the 5 piles in Panama was covered with roll roofing after 18 months of exposure. Further rain-wetting was thus prevented, and one year later the wood moisture conetnt was appreciably lower and the percentage of failures was much higher than in the comparable uncovered pile:

	Per cent failed	
	Not covered	Covered
3-minute dips	5	35
Pressure-treated	5	25
Untreated	42	100

The decay in the covered pile was mostly typical brown-cubical rot as caused by many Basidiomycetes rather than the black wet-rot type predominating in the uncovered piles.

No difficulty was experienced in painting any of the treated wood, including that pressure-treated with pentachlorophenol (Tables 5, 14). Similarly, there was no evidence that paint durability was less on the treated than on the untreated units. A few samples given 3-minute dips in sodium pentachlorophenate in water plus 4 per cent emulsified paraffin wax were successfully painted, and the films have remained intact after 3 years' outdoor storage. In all cases, the paint used was TT–E–485b, Type II, olive drab, and was not applied until a week or more after preservative treatment.

Most preservatives were applied at three concentrations: 1) that ordinarily used in wood preservation or thought to be most suitable, 2) half this concentration, and 3) double the first concentration. With the boxes there was, in general, surprisingly little difference in decay rate with different concentrations (Tables 2, 3), and some boxes with double concentration failed sooner than those with lighter treatments. With the better matched simulated-box units, rate of decay was in direct proportion to concentration (Tables 13, 14). With copper naphthenate, concentration seemed to be more critical than with pentachlorophenol (Table 14). Wood treated with copper naphthenate at 0.6 per cent Cu decayed at a significantly faster rate than at 1 per

Table 21.—SUBTERRANEAN TERMITE ATTACK ON M-22 BOXES ON NON-POISONED SOIL IN THE PANAMA CANAL ZONE

Treatment	Proportion of boxes that failed[1] [2]		
	0.5 years	1.5 years	2.5 years
	Per cent		
Oil Solutions, 3-Minute Dips			
Benzene hexachloride (0.5% gamma)	13	13	13
Copper naphthenate, 1% Cu plus WR	25	25	50
Copper naphthenate, 2% Cu plus WR	25	25	25
Copper pentachlorophenate, 5% plus WR	13	13	13
Copper 3-phenyl salicylate, 2.5% plus WR	30	50	50
Copper 3-phenyl salicylate, 5.0% plus WR	25	38	50
Copper 8-quinolinolate, 0.3% plus WR	13	13	13
Copper 8-quinolinolate, 0.6% plus WR	25	63	75
Copper 8-quinolinolate, 0.3% plus 0.5% gamma benzene hexachloride	25	25	25
Orthophenylphenol, 5% plus WR	13	25	38
Orthophenylphenol, 10% plus WR	0	0	0
Pentachlorophenol, 5% plus WR	25	25	25
Pentachlorophenol, 10% plus WR	0	0	13
Pentachlorophenol, 5% plus 0.5% gamma benzene hexachloride	13	13	13
Phenyl mercuric oleate, 0.3% plus WR	25	25	63
Phenyl mercuric oleate, 0.6% plus WR	13	50	63
Product containing 23% zinc naphthenate, 2.5% (coco) dodecyl-amine salt of tetrachlorophenol, and 28.5% water repellent			
25.0%	38	38	38
37.5%	13	25	25
Rosin amine D. pentachlorophenate, 5.5% plus WR	25	25	38
Rosin amine D pentachlorophenate, 11.0% plus WR	25	50	75
Tetrachlorophenol, 5% plus WR	25	25	25
Tetrachlorophenol, 10% plus WR	13	25	25
Water repellent only	46	63	63
Zinc alkyl sulphonate, 5.7% plus WR	25	25	25
Zinc naphthenate, 1% Zn plus WR	25	25	25
Zinc naphthenate, 2% Zn plus WR	25	25	38
Water Solutions, 3-Minute Dips			
Copper ammonium fluoride, 10%	25	25	50
Copper ammonium fluoride, 20%	25	25	38
Copper ammonium fluoride, 10% plus WR	25	25	25
Product containing sodium salts of dimethyl dithiocarbamic acid and 2-mercapto benzothiazole, and pentachlorophenol, 7.5%	25	25	25
Rosin amine D acetate, 5%	13	38	50
Rosin amine D acetate, 10%	25	25	25
Sodium pentachlorophenate, 5.7%	25	25	38
Sodium pentachlorophenate, 11.4%	13	13	13
Sodium pentachlorophenate, 2.0% plus borax 3%	13	25	38
Sodium pentachlorophenate, 4.0% plus borax 4%	13	13	25
Sodium pentachlorophenate, 2.0% plus borax 3% plus WR	25	25	25
Sodium tetrachlorophenate, 5.7%	13	25	25
Sodium tetrachlorophenate, 5.7% plus WR	25	25	25
Oil Solutions, Pressure Treatments			
Pentachlorophenol, 5%	0	0	13
Pentachlorophenol, 5% plus WR	0	13	13
Water Solutions, Pressure Treatments			
Copperized chromated zinc chloride	0	0	0
Tanalith	0	0	0
Celcure	0	0	0
Untreated	56	75	81

[1] Percentage of boxes in rating classes 4 and 5.
[2] High decay ratings prevented accurate termite ratings after 2.5 years' exposure.

cent Cu. Other tests (6) also indicate that copper concentrations of less than 1 per cent in treating solutions are likely to be ineffective when applied as dips or soaks.

During the 3.1 years of exposure, 10-second to 3-minute dips in 5 per cent pentachlorophenol plus a water repellent or copper naphthenate (2 per cent Cu) plus a water repellent have given almost complete protection to wire-bound crates made of rotary-cut veneer (Table 7, Figure 7). This was expected because of the high absorptions secured.

Discussion and Summary

In interpreting results of these tests, it is important to remember that composite piles were used, so that boxes treated with different chemicals were in contact horizontally in the piles. This arrangement led to some border effects in rate of corrosion of galvanized strapping, of water pickup, and of decay. A box treated with a satisfactory preservative often had significant metal corrosion, became wet sooner, and developed more decay on sides in contact with a box that had an unsatisfactory treatment.

Increased wetting and decay, but not metal corrosion, also occurred next to untreated boxes. These border effects tended to minimize differences and to decrease the showing of the better treatments. The uncontrollable variability in wood (amount of heartwood and species) from box to box also makes it unwise to accept small differences among treatments as significant. For the simulated-box tests, wood was carefully selected and matched among treatments, so that smaller differences became significant.

Three-minute dips did not give good protection against subterranean termites. Pressure treatments also failed in this respect when appreciable amounts of wood of poor treatability were present. The data suggest that, in regions where subterranean termites abound, a soil poison should be used prior to box storage: 1) in temperate regions when boxes are dip-treated, or, if appreciable amounts of heartwood are present, pressure-treated, and 2) in tropical regions for boxes regardless of the type of treatment.

In these tests, DDT was used as a soil poison (Fig. 4B), but any of the following treatments should suffice (3): Chlordane (8 lb.), dieldrin (4 lb.), DDT (60 lb.), or BHC (6.4 lb. gamma), each in 100 gallons of No. 2 fuel oil, and applied to the soil after debris and leaf litter are scraped back.

All these solutions should be evenly distributed over the area to be covered by boxes (plus a 4-foot border) at the rate of 2 pints per square foot in the tropics and 1 pint in temperate regions. Satisfactory application can be accomplished with a garden sprinkling can. If the soil is compacted and a slope is present, a light scarification will reduce surface runoff. All the poisons except DDT may be applied as water emulsions also.

Water repellents did not prevent water from accumulating in boxes stored for long periods in close piles where drying between showers was slow. Even during short periods of outdoor storage in areas of high rainfall, such as south Mississippi, water repellents did not prevent swelling to approximately maximum size. Ammunition boxes for outdoor storage must be designed, therefore, as was the M22 box, to be openable when the wood is either air dry or fully expanded. Water repellents were effective, however, in keeping boxes reasonably dry for 3 or 4 months' outdoor storage in Mississippi. During such

Table 22.—EFFECT OF 2 COATS OF PAINT (TT-E-485b) ON TERMITE ATTACK ON M-22 BOXES TREATED WITH VARIOUS PRESERVATIVES AND EXPOSED WITHOUT COVER FOR 38 MONTHS IN SOUTH MISSISSIPPI

Treatment	Proprotion of boxes in each rating class[1]									
	Painted					Unapinted				
	0–1	2	3	4	5	1	2	3	4	5
	Per cent									
Oil Solutions, 3-Minute Dips										
Copper naphthenate, (1% Cu) plus WR	88	0	13	0	0	75	0	25	0	0
Copper 3-phenyl salicylate, 2.5% plus WR	88	13	0	0	0	75	0	25	0	0
Copper 8-quinolinolate, 0.3% plus WR	88	0	13	0	0	75	0	0	25	0
Mineral spirits (aliphatic) 100%	75	13	13	0	0	75	0	13	13	0
Mineral spirits (aliphatic) 100%, plus WR	75	13	13	0	0	75	0	19	6	0
Orthophenylphenol, 5% plus WR	75	13	13	0	0	75	0	25	0	0
Pentachlorophenol, 5% plus WR	75	25	0	0	0	75	0	13	13	0
Phenyl mercuric oleate, 0.3% plus WR	63	13	25	0	0	75	0	13	13	0
Product containgin 23% zinc naphthenate, 2.5% (coco) dodecyl-amine salt of tetrachlorophenol, and 28.5% water repellent, 37.5%	75	0	25	0	0	75	0	25	0	0
Rosin amine D pentachlorophenate, 5.5% plus WR	75	25	0	0	0	75	0	13	13	0
Zinc alkyl sulphonate, 5.7% plus WR	75	0	13	13	0	75	0	0	25	0
Zinc naphthenate, (1% Zn) plus WR	75	13	13	0	0	75	0	0	25	0
Water Solutions, 3-Minute Dips										
Copper ammonium fluoride, 10%	88	0	13	0	0	75	13	13	0	0
Rosin amine D acetate, 5%	75	0	25	0	0	75	0	13	13	0
Sodium pentachlorophenate, 5.7%	88	13	0	0	0	75	0	25	0	0
Sodium pentachlorophenate, 2.0% plus borax 3.0%	88	0	13	0	0	75	0	13	13	0
Sodium tetrachlorophenate, 5.7%	88	0	13	0	0	75	0	13	13	0
Oil Solution, Pressure Treatment										
Pentachlorophenol, 5%	100	0	0	0	0	88	0	13	0	0
Untreated	75	6	19	0	0	75	0	12	6	6

[1] Ratings on a basis of 0 (none) to 5 (destroyed).

Table 23.—EFFECTIVENESS OF 5% PENTACHLOROPHENOL PLUS A WATER REPELLENT APPLIED AS A 3-MINUTE DIP IN PREVENTING WATER PICKUP BY SIMULATED BOXES OF DIFFERENT WOOD SPECIES AFTER DIFFERENT PERIODS OF EXPOSURE IN SOUTH MISSISSIPPI

Wood species	Average moisture content									
	Treated								Untreated	
	1 month		2.5 months		12 months		18 months		2.5 months	
	O	I[1]	O	I	O	I	O	I	O	I
	Per cent of oven-dry weight									
Southern pine, sapwood	18	20	21	32	17	37	29	45	80	86
Southern pine, heartwood	16	19	18	25	17	23	18	33	46	69
Ponderosa pine, sapwood and heartwood	21	26	26	38	22	40	26	43	64	90
Eastern white pine, sapwood and heartwood	16	21	25	31	22	39	18	56	--	111
Western hemlock, probably sapwood and heartwood	18	21	26	36	21	36	22	33	51	80
Douglas-fir, mainly heartwood	16	18	17	23	15	25	15	30	39	66
Sweetgum, sapwood (sap gum)	16	19	21	33	19	27	23	27	59	71
Sweetgum, heartwood (red gum)	15	20	16	27	15	26	19	29	39	54
Yellow-poplar, sapwood	17	19	25	24	23	28	25	36	42	80
Yellow-poplar, heartwood	19	19	23	33	18	39	20	37	46	62
Tupelo, probably sapwood and heartwood	15	20	19	33	18	28	20	38	41	61

[1] O and I refer to units in tiers exposed at the outside and inside of the pile, respectively.

Table 24.—EFFECT OF LENGTH OF IMMERSION OF M-22 BOXES IN THREE WATER REPELLENT SOLUTIONS[1] ON WATER PICKUP DURING 2.1 YEARS' EXPOSED IN SOUTHERN MISSISSIPPI

Immersion period[2]	Average weight[3]		
	0.3% copper 8-quinolinolate	5% pentachlorophenol	Copper naphthenate (1% Cu)
	Pounds		
5 seconds	9.9	11.5	7.5
10 seconds	9.8	10.0	8.5
1 minute	9.8	10.4	8.5
2 minutes	9.9	10.4	8.5
3 minutes	9.7	10.0	8.7
10 minutes	10.0	11.5	8.7

[1] The water repellent was WR-7.
[2] See Table 11 for preservative retentions.
[3] Because of differences in exposure conditions comparisons between chemicals are not valid.

Table 26.—EFFECTIVENESS OF TOXIC WATER REPELLENTS APPLIED AS 3-MINUTE DIPS IN REDUCING ABSORBENCY OF MOLDED AND NON-INFECTED SOUTHERN PINE SAPWOOD AFTER VARIOUS EXPOSURE PERIODS IN SOUTHERN MISSISSIPPI

Wood condition and treatment	Absorption of preservative Grams/unit	Average moisture content 0.5 months	0.75 months	4 months	4.2 months	6 months
		Per cent of oven-dry weight				
Molded wood						
Untreated	0	50	73	61	63	67
5% pentachlorophenol, plus WR-7	170	15	17	16	17	20
Copper naphthenate (2% Cu) plus WR-7	146	15	18	17	19	21
Non-infected wood						
Untreated	0	29	38	28	35	47
5% pentachlorophenol, plus WR-7	32	14	15	17	19	20
Copper naphthenate (2% Cu) plus WR-7	30	15	17	17	20	23

Table 27.—RELATIVE EFFECTIVENESS OF WATER REPELLENTS APPLIED AS 3-MINUTE DIPS WITH AND WITHOUT FUNGICIDES IN PREVENTING MOISTURE PICKUP BY SOUTHERN PINE SAPWOOD SIMULATED BOXES EXPOSED IN SOUTHERN MISSISSIPPI

Treatment	Average moisture content[1] June 1953	Aug. 1953	Dec. 1953	May 1954	April 1955
Test A, exposed Jan. 1953					
5% pentachlorophenol, plus WR-7	20	25	38	26	54
Commercial water repellents alone, average solids, paintable	21	32	58	33	67
Commercial water repellents alone, high solids, non-paintable	19	21	27	21	39
3% pentachlorophenol, without WR	65	82	--	59	--
	July 1954	Sept. 1954	Dec. 1954	April 1955	May 1955
Test B, exposed May 1954					
5% pentachlorophenol, plus WR-7	13	14	16	16	14
5% pentachlorophenol, plus commercial product, normal solids	16	14	17	17	14
Water repellents alone, WR-7	18	16	20	22	18
Water repellents alone, commercial product, normal solids	17	15	18	19	16
5% pentachlorophenol, without WR	36	32	40	43	31

[1]Averages of units on outside and inside of the piles.

periods, the boxes remained too dry to decay, and 15 to 20 per cent (of the loaded weight of approximately 43 pounds) lighter than untreated boxes. Thus they were more easily handled and could be shipped at lower cost.

Because of this effect of water repellents and the generally satisfactory decay protection afforded by copper naphthenate and pentachlorophenol, the most satisfactory treatments were with preservatives covered by Federal Specification TT-W-572. It is suggested that such preservatives be used for most container treatment, whether applied by dips, soaks, or pressure. When protection from periodic wetting is not needed, however, treatment with the water-borne preservatives according to Federal Specification TT-W-571 should be suitable for some type of containers, except possibly for longtime fully exposed storage under tropical conditions.

Since decay was negligible in aboveground boxes after 5 years' exposure in Wisconsin, treatment in regions of similar or drier climate seems unnecessary if boxes to be held for this period can be stored off the ground. A layer of treated wood or strips to keep the bottoms off the ground should afford adequate protection. Should boxes be made of a more decay-susceptible wood than eastern white pine, a 3-minute dip probably would give good protection for more than 5 years, or well beyond the goal set for these studies.

While no dip treatment afforded five years' protection under tropical exposure, three approached it: tetrachlorophenol 10 per cent, copper pentachlorophenate 5 per cent, and copper naphthenate 2 per cent Cu. The first of these had a uniform decay rating of "3" after 4.5 years and probably will fail completely in a short time; the second was too corrosive to metal and had decay ratings of "3" or higher on 73 per cent of the boxes; the last had decay ratings of "2" or less on 60 per cent of the boxes. Consequently, for dip treatment of boxes for tropical exposure, only copper naphthenate (2 per cent Cu) can be recommended at this time, and then only for 3 years' protection.

The test data indicate that, for longtime protection under tropical exposure, pressure treatment with an oil-borne preservative may be necessary. After 4.5 years' exposure in Panama, no box with a retention of at least 4 lbs. of pentachlorophenol per cu. ft. had failed. It should be remembered, however, that shipping boxes are often made from lower grades of lumber that contain more knots and a higher proportion of heartwood than do higher grades. This will interfere with adequate penetration by pressure treatment, and certain boards may not be adequately protected.

Under the intermediate exposure conditions of south Mississippi, several dip treatments gave adequate protection for 5 years. When all factors are considered, the most satisfactory are those covered by Federal Specification TT-W-572, or copper naphthenate and pentachlorophenol. For the period of the test (5 years) there was no marked advantage in the use of pressure treatments. For longer exposures, pressure treatments very likely would be superior.

Several other preservatives gave satisfactory decay control in Mississippi and Panama, but for one reason or another are not recommended at this time: 1) copper pentachlorophenate was difficult to handle and corrosive to metal, 2) rosin amine D pentachlorophenate was slightly too cor-

Table 25.—EFFECT OF LENGTH OF IMMERSION OF SOUTHERN PINE SAPWOOD IN 5% PENTACHLOROPHENOL, PLUS A WATER REPELLENT, ON WATER PICKUP AFTER VARIOUS PERIODS OF EXPOSURE IN AN UNCOVERED PILE IN SOUTHERN MISSISSIPPI

Immersion period	Absorption of treating solution lb./cu. ft.	Average moisture content 1 month	2.2 months	3.7 months	19 months
		Per cent of oven-dry weight			
30 seconds	1.5	28	36	56	54
1 minute	1.5	28	36	53	53
3 minutes	2.0	30	37	52	47
10 minutes	2.2	29	36	52	50

Table 28.—COMPARATIVE EFFECTIVENESS OF DIFFERENT WATER REPELLENTS IN OIL SOLUTIONS OF 5% PENTACHLOROPHENOL APPLIED AS 3-MINUTE DIPS TO SOUTHERN PINE SAPWOOD SIMULATED BOXES EXPOSED FOR VARIOUS PERIODS IN SOUTHERN MISSISSIPPI

Treatment	Average moisture content July 1954 O	I	April 1955 O	I	Oct. 1956 O	I
	Per cent of oven-dry weight					
Test A, established May 1954						
No water repellent	28	37	31	54	--	--
Plus WR-7[1]	13	14	15	17	23	25
Plus 20% linseed oil[2]	24	--	21	--	35	--
Plus 12% alkyd resins[3]	22	--	25	--	50	--
Test B, established Aug. 1954						
Plus WR[4]	14	--	17	--	18	--
Plus alkyd resins[5]	21	--	18	--	30	--
Untreated	39	--	33	--	77	--

[1]8% methyl ester of hydrogenated rosin and 2% paraffin wax.
[2]20% linseed oil and 0.07% cobalt.
[3]12% alkyd resin (TT-R-266, Type I).
[4]Commercial solution, repellent not disclosed.
[5]Commercial preparation labeled "Army 3-186-Type II".

rosive to metal in Panama, 3) sodium pentachlorophenate alone or with borax was too corrosive to metal, and 4) pressure treatments with Celcure and copperized chromated zinc chloride were too corrosive to metal and did not afford water repellency.

Whether or not chemical protection of shipping containers will be economically feasible depends on the saving due to longer service life in comparison to the cost of treatment. Cost can be fairly accurately estimated, but the length of service is intangible because of the uncertainty of storage conditions. Many boxes, especially in peace-time, are stored indoors and it is not possible under many military conditions to predetermine which containers will be subjected to a specific hazard. Also, as needs change, containers may be reshipped to other locations with a different exposure hazard.

With such a relatively high-cost container as the M22 box, the expense of a dip treatment may be justified even if a relatively small percentage of the boxes are subjected to moderate to high decay hazard. With cheaper containers, the advantage of treating is less obvious unless it is definitely known that the treated boxes will be subjected to an appreciable decay hazard. Service life also influences the economics of treatment. Containers for longtime storage or for re-use justify treatment more than those to be used a short time and then discarded.

Under the conditions of these tests, the number of years of uncovered outdoor storage on poisoned soil necessary to produce 5, 10, and 20 per cent failure of M22 boxes were calculated to be:

Treatment	Mississippi			Panama		
	5%	10%	20%	5%	10%	20%
None	2.5	3.0	3.5	1.5	1.75	2.25
3-minute dip[1]	4.5	5.5	6.5	3.0	3.5	4.5
Pressure[2]	6.0	10.0	18.0	5.0	7.0	10.0

[1]In Mississippi, copper naphthenate (1% Cu) or 5% pentrachlorophenol, and in Panama, copper naphthenate (2% Cu), each with a water repellent.
[2]Pentachlorophenol with minimum retentions of 4 lbs. per cu. ft. of 5% solution.

These data indicate that, under the storage conditions encountered, the 3-minute dips would be satisfactory for about 5 years' exposure in the wetter parts of the United States, and 3 years under tropical jungle exposure. For longer exposure, pressure treatments might well be considered.

The tests further indicate that if untreated boxes were stored on treated strips on poisoned soil no treatment would be needed if a watertight tarpaulin or other cover were provided.

With fully exposed, dip-treated boxes, the rate of deterioration can be reduced by painting the boxes after treatment.

Table 29.—RELATIVE EFFECTIVENESS OF WAX EMULSIONS AND SILICONE AS WATER REPELLENTS WHEN ADDED TO WATER SOLUTIONS OF FUNGICIDS AND APPLIED AS 3-MINUTE DIPS TO SOUTHERN PINE SAPWOOD SIMULATED BOXES EXPOSED FOR VARIOUS PERIODS IN SOUTHERN MISSISSIPPI

Treatment	Average moisture content									
	May 1953		Aug. 1953		Dec. 1953		May 1954		Apr. 1955	
	O[3]	I	O	I	O	I	O	I	O	I
	Per cent of oven-dry weight									
Test A, exposed Dec. 1952										
5% pentachlorophenol plus WR (Oil)	20	22	23	26	34	42	25	27	45	62
5% sodium pentachlorophenate plus 4% wax[1]	18	21	19	29	21	54	19	45	42	53
5 sodium pentachlorophenate plus 8% wax[1]	18	21	21	26	--	--	19	41	29	82
Untreated	52	--	74	--	--	--	--	--	--	--
Test B, exposed April 1953										
5% sodium pentachlorophenate	39	36	66	70	61	79	33	57	43	64
5 sodium pentachlorophenate plus 4% wax[1]	18	20	22	30	19	38	16	28	18	55
5% sodium pentachlorophenate plus 1% silicone[2]	18	19	22	28	25	45	17	35	--	--

[1]Wax was a 50% emulsion, Ceremul A.
[2]Silicone SC-50 supplied by General Electric Company.
[3]O and I refer to units in tiers exposed at the outside and side of the piles, respectively.

For either dip or pressure treatment, only fabricated boxes or shooks should be treated. Dip treatment of boxes can be accomplished with automatic machines. Pressure treatment of boxes would probably be prohibitively costly because of the small wood volume that could be treated in a charge, but the treatment of shooks would remove this difficulty. The making of boxes from treated lumber is not recommended because freshly cut surfaces resulting from manufacture would need retreatment.

Wire-bound crates of rotary-cut southern hardwood veneer decay so fast that it is desirable to treat them if outdoor storage beyond a few months in southern United States is contemplated. High absorptions in veneer boxes, as well as in lumber boxes made of fungus-infected lumber (8), can be deleterious. Even with light solvents and normal handling procedures, sufficient oil can remain in the wood to harm box contents. Serious dissolving of asphalt in lining materials, with resultant damage to ammunition, has been observed in actual use. Rotary-cut veneer boxes or boxes made of stained or molded lumber should be treated with care, often with only instantaneous dips, and subjected to particularly favorable drying conditions to allow evaporation of the solvent.

The current tests leave a number of questions unanswered. Chief among these is the problem of metal corrosion by some of the standard water-borne preservatives. Some corrosion can be attributed to the direct contact of strapping with the treating solutions, but in the waterlogged wood of many of the test boxes, active and serious corrosion began some months after treatment. Also, water-borne pressure treatments of higher retentions should be tried under tropical conditions because other tests (1) indicate these would give a much longer service life in Panama. For other types of crates and boxes it will be necessary to determine whether a 3-minute dip will afford as much protection to 8/4 and thicker lumber as it does to 4/4 lumber. Plywood containers were not tested, and it can only be surmised that they would react similarly to lumber boxes, and certainly only if water-resistant glues were used.

Literature Cited

1. Blew, J. O. 1958. Comparison of wood preservatives in stake tests. U. S. Forest Products Lab. Report 1761.
2. Brown, F. L., R. A. Moore, and R. A. Zabel. 1956. Absorption and penetration of oil-soluble wood preservatives applied by dip treatment. N. Y. State College of Forestry Tech. Bul. 79.
3. Johnston, H. R. 1958. Tests with soil poisons for controlling subterranean termites. Pest Control 26 (2): 9.
4. McKnight, J. S. 1957. Some physical factors influencing the effectiveness of preservatives. Forest Prod. J. VII (12): 441.
5. Sutherland, J. H., W. H. Johnston, and O. Maass. 1934. Further investigations of the penetration of liquids into wood. Canadian Jour. Res., 10: 36.
6. Verrall, A. F. 1953. Decay protection in wooden steps and porches through proper design and protective treatments. J. FPRS. III (4): 54.
7. Verrall, A. F. 1953. Factors leading to possible decay in wood siding in the south. U.S.D.A. For. Path. Special Release 39.
8. Verrall, A. F. 1957. Absorption and penetration of preservatives applied to southern pine wood by dips or short-period soaks. U.S.F.S. Southern For. Expt. Sta. Occasional Paper 157.

New Tool

FOR MEASURING ADHESION OF COATINGS TO WOOD [1]

G. E. Naslund and B. O. Hallberg
Test Group Leader and Development Engineer, Weyerhaeuser Timber Co., Longview, Wash.

This new instrument and technique was developed specifically for wood products. It relies on pressure-sensitive tape and the self-recording, swinging-impact principle for removing the surface coating. Its reliability and accuracy should make it valuable in quality control and in research and development.

Fig. 1.—A new self-recording pendulum-type apparatus for measuring the adhesion of surface coatings to structural materials.

During the past few years, many tests have been developed for measuring the adhesion of surface coatings to various metallic and nonmetallic surfaces. In reviewing these tests, it was found that they were not readily adaptable to measuring and recording the adhesion of paints to modified wood products. The tests that were reviewed were either too subjective or were too complicated to run effectively and efficiently.

In one of the tests, pressure-sensitive tape was pulled from the painted surface with a quick, lifting hand motion, and the resulting paint failure was estimated subjectively as either good, fair, or poor. It was observed that a direct relationship existed between per cent paint failure and energy required to remove the tape from the test surface.

The primary objective then became to mechanize this test where ever possible to give a test that would accurately measure and record the energy required to remove the paint from the test surface.

The purpose of this paper is to show how a simple test was mechanized and converted into a very effective tool for measuring and recording, in mathematical terms, the adhesion of paints to modified wood products.

The original and primary objective was to develop a test for determining the adhesion of various base or undercoat finishes to hardboard, so this paper will be centered around the data gathered during this study.

Development of Testing Equipment

The first problem was the selection of a standard tape that would always give the desired range of adhesive sensitivity and would possess the required tensile strength. The tape that most nearly met the requirements was ¾ inch Scotch brand pressure-sensitive Cellophane tape number 600, which has the following published physical properties:

	Average Value
1. Tensile strength, lbs./in. of width	30
2. Adhesion, ounces/inch of width	60
3. Total thickness	.003
4. Stretch, % at break	15

After the tape was selected, it was necessary to design or select a machine that would not only mechanically simulate the lifting hand motion in removing the paint from the sample, but would also measure and record the energy required to remove the paint. Several machines were investigated, and an impact-type of apparatus shown in Fig. 1 was selected.

The machine operates on the principle of a falling pendulum, which possesses 2 foot pounds of potential energy at its upper-most position. As the pendulum falls to the bottom of its swing (Fig. 2), it engages the tape and proceeds to remove it as shown in Fig. 3. The energy absorbed is recorded on the back swing of the pendulum as shown in Fig. 4. The most desirable angle of tape removal is 90° to the surface of the sample but, as shown in Fig. 5, it was necessary to compromise on this angle of removal so that it varied equally on either side of 90°.

After the basic machine was selected, accessory jigs and fixtures were selected to make the testing procedure as mechanical as possible. First of all, a jig was needed that would locate the tape on the specimen precisely every time, and would each time give the exact length of tape required. This jig is shown in Fig. 1 in the center foreground.

Another necessary accessory item was the tape pressurizing tool. This was done hydraulically by the use of a hand-operated press, which had a pressure-indicating gage attached to the oil reservoir. The sample, with its tape, was located between the pressure

[1] Presented at Session XII, Wood Finishing, FPRS 12th National Meeting, held June 22–27, 1958, in Madison, Wis.

The Authors: Glen Naslund attended the University of Idaho, joined Weyerhaeuser in 1944. He is responsible for development of new test methods.

Bruce Hallberg holds a BS in mechanical engineering from the University of Illinois, joined Weyerhaeuser in 1956.

Fig. 2.—Sample positioning arrangement and pendulum action just prior to engagement.

Fig. 3.—Pendulum action during tape removal.

Fig. 4.—Pendulum action and tape retention during energy recording.

plates of the press and, by means of hydraulic pressure, the tape was uniformly pressed onto each sample. A portion of the tape extended beyond one end of the sample. This tool is shown on the extreme left of Fig. 1.

To locate the sample in the machine rigidly and in the correct position, it was necessary to develop a locating or positioning fixture. Once the sample was properly placed in the positioning fixture, a dowel was located in the pick-up position, and the extending end of the tape was secured to it. This dowel is then picked up by the pendulum as it reaches the bottom of its swing.

The equipment was designed with simplicity and speed of operation in mind. Human judgment, which was present in the original test procedure, where the tape was removed by hand, has been eliminated by using mechanical devices to evaluate adhesion.

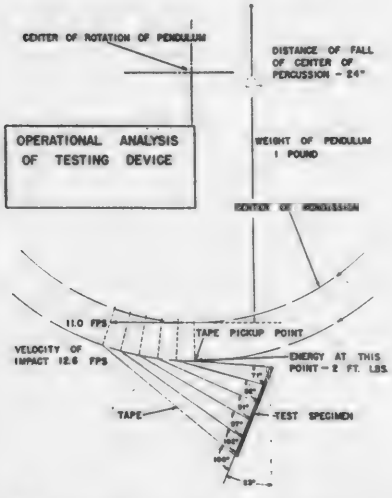

CENTER OF ROTATION OF PENDULUM
DISTANCE OF FALL OF CENTER OF PERCUSSION - 24"
OPERATIONAL ANALYSIS OF TESTING DEVICE
WEIGHT OF PENDULUM 1 POUND
CENTER OF PERCUSSION
11.0 FPS
TAPE PICKUP POINT
VELOCITY OF IMPACT 12.6 FPS
ENERGY AT THIS POINT - 2 FT. LBS.
TAPE
TEST SPECIMEN

Fig. 5.—Diagram of operational characteristics of tool action.

Test Procedure

To be an effective tool in both the quality control department and the research department, the test must be capable of reproducing results on many hundreds of samples per day, if necessary. To facilitate this objective, as many mechanical time savers as possible have been incorporated into the test equipment, and the sequence of operations has been kept as simple and orderly as possible.

The first operation is preparing the samples to be tested for adhesion of surface coatings. The machine has been designed to handle samples 3 by 5 inches by any thickness from 1/10 up to ¾ inch. Other sample sizes can be tested with minor adjustments to the positioning fixture. After the sample has been cut to size, the surface coating can be applied in several ways. The test area is ¾ by 5 inches as shown in Fig. 6.

Because of the varying film strengths and drying times of the coatings in question, it was necessary to standardize on each of these items to minimize and control their effect on test results. The Bird applicator was selected as the standard method of application because of its simplicity, reproducibility, and relative inexpensiveness. Drying times used together with choosen film thicknesses are as follows:

Base coat	Drying times hours	Wet film thickness, mils
Lacquer	2 to 16	5
Latex, flat coat	16 to 24	4
Oil base, interior	24 to 32	3

Once the sample has been prepared and the surface coating has cured to the required specifications, the sample is ready for testing. The first operations are to locate, compress to 125 psi, and cut the tape to the correct length. The tape-locating jig and the hydraulic press are used to perform these operations.

After the tape has been applied, the test specimen is positioned in the jig and the wood dowel is located and tape secured to it as shown in Figs. 6 and 2. Once the sample has been secured properly, the pendulum is released from its ready position. At the base of its swing, it picks up the dowel and proceeds to remove the tape, with or without the paint. A portion of the kinetic energy has been removed from the swinging pendulum by the resistance to paint removal. This removed energy is recorded on the back swing of the pendulum in foot pounds. A definite relationship exists between the machine reading in foot pounds and the per cent paint failure.

To take into account the various factors that affect the machine evaluations, the reading is corrected for windage and friction as shown in Fig. 12.

Analysis of Machine Performance

To establish the reproducibility as well as the relationship of machine values to per cent paint failure, the device

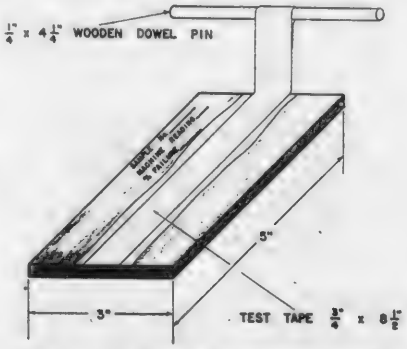


Fig. 6.—Test sample arrangement; tape, paint and dowel pin.

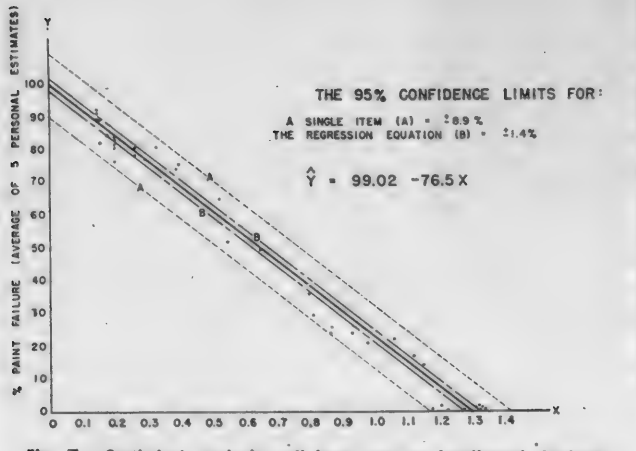

% PAINT FAILURE (AVERAGE OF 5 PERSONAL ESTIMATES)
THE 95% CONFIDENCE LIMITS FOR:
A SINGLE ITEM (A) = ±8.9 %
THE REGRESSION EQUATION (B) = ±1.4%
Ŷ = 99.02 -76.5 X

Fig. 7.—Statistical analysis—oil base coat on hardboard. Performance characteristics and the relationship of machine values to human estimates of per cent paint failure.

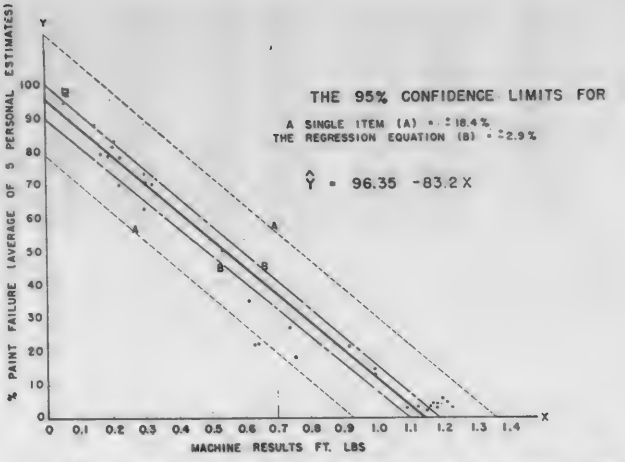

% PAINT FAILURE (AVERAGE OF 5 PERSONAL ESTIMATES)
THE 95% CONFIDENCE LIMITS FOR
A SINGLE ITEM (A) = ±18.4%
THE REGRESSION EQUATION (B) = ±2.9%
Ŷ = 96.35 -83.2 X
MACHINE RESULTS FT. LBS

Fig. 8.—Statistical analysis—lacquer coat on hardboard. Performance characteristics and the relationship of machine values to human estimates of per cent paint failure.

performance was analyzed statistically. The results of the analysis, which compares machine values to human estimates, is shown in Figs. 7, 8, and 9. These results indicate that: 1) there is a highly significant variation in estimating per cent paint failure from person to person, 2) the mathematical relationship that exists between machine values and the average of five personal evaluations of per cent paint failure is independent of the paint used to coat the hardboard samples, 3) replicate machine evaluations have shown that variations inherent in the device and tape are small and are a function of the level of the machine reading.

The pictorial comparison of machine readings and per cent paint failure, shown in Fig. 10, clearly shows the straight line relationship that exists between machine values and per cent paint failure.

To compare the results from this device with other commonly used methods of evaluating the adhesion of surface coatings to wood products, several hardboard test samples were prepared and sent to an outside firm for their evaluation of the adhesion. All test samples were coated with a lacquer base coat. The methods this firm used to evaluate the adhesion of the lacquer base coat were the crosshatch test and the knife adhesion test. The same samples were then evaluated by the paint adhesion tester, and the results of the three tests were tabulated and compared. The results of these three tests are shown in Table 1. It can be seen from this comparison that the machine values of 0.09 and 0.85 foot pounds compare, respectively, with the subjective ratings of very poor and good.

To evaluate paint adhesion effectively by either the crosshatch test or the knife test, a person skilled in the art is required. The subject adhesion testing device will measure adhesion more accurately and without the need of an experienced operator.

Various types and grades of leading hardboards were tested to determine the adhesion of lacquer basecoat, flat latex, and oil-base undercoat to the hardboard surfaces. The results of this test, which are shown in Table 2, were

Table 1.—(UPPER) COMPARISON OF KNIFE ADHESION AND CROSS HATCH TESTS WITH THE PAINT ADHESION TESTER. (LOWER) RELATIONSHIP OF MACHINE VALUES TO PER CENT FAILURE AND SUBJECTIVE RATINGS

Sample	Knife adhesion	Cross hatch % failure	Subject tester Ft. lbs.	Subject tester % failure
A	Good	2	.80	35
B	Good	2	.87	30
C	Good	2	.94	25
D	Bad	100	.09	95
E	Bad	100	.09	95
F	Good	0	1.30	0

Resistance to removal ft. lbs.	Estimated % Paint failure	Subjective rating
1.30	0– 2	Superb
.85–1.30	2– 25	Excellent
.45– .85	25– 50	Good
.25– .45	50– 75	Fair
.06– .25	75–100	Poor

Table 2.—PAINT ADHESION PROPERTIES OF LEADING COMMERCIAL HARDBOARD TYPES

	Resistance Removal, Foot Lbs. Lacquer basecoat	Flat latex	Oil base undercoat
A. Standard Board			
S-1-S: Type-A	.92	.90	1.15
S-1-S: Type-B	.67	.17	.95
S-1-S: Type-C	.06	.07	.34
S-2-S: Type-A	.07	.34	.91
S-2-S: Type-D	.07	.29	1.01
B. Low Density Board			
S-1-S: Type C-1	.06	.11	.63
S-1-S: Type C-1	.06	.12	.57
C. Treated Board			
S-1-S: Type-A	1.00	.16	1.20
S-1-S: Type-B	.46	.40	1.18
S-1-S: Type C-1	1.00	.26	1.25
S-1-S: Type C-2	.07	.15	1.34
S-2-S: Type-A	.52	.55	1.06
S-2-S: Type-D	1.04	.81	1.20

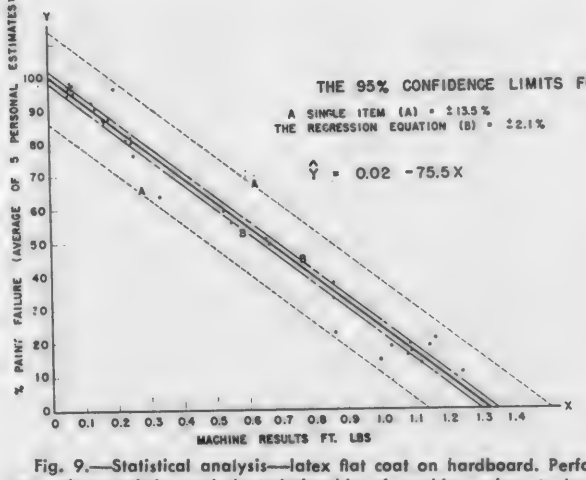

% PAINT FAILURE (AVERAGE OF 5 PERSONAL ESTIMATES)
THE 95% CONFIDENCE LIMITS FOR:
A SINGLE ITEM (A) = ±13.5 %
THE REGRESSION EQUATION (B) = ±2.1%
Ŷ = 0.02 -75.5 X
MACHINE RESULTS FT. LBS

Fig. 9.—Statistical analysis—latex flat coat on hardboard. Performance characteristics and the relationship of machine values to human estimates of per cent paint failure.

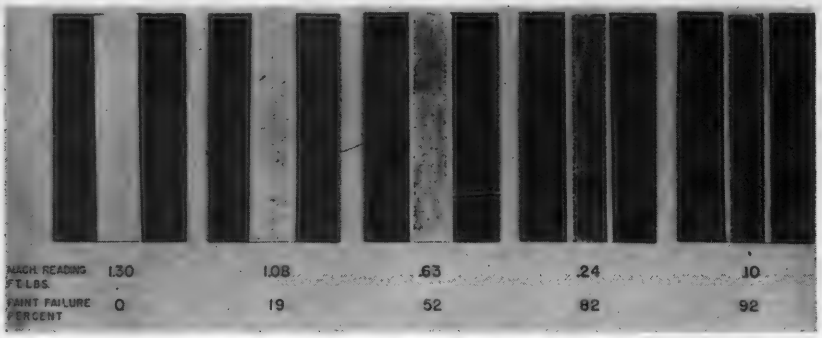


Fig. 10.—Relationship of machine values to per cent paint failure. This correlation has been proven statistically and includes lacquer, latex, and oil base paints.

compared with other laboratory and service results. In all cases, the results compared favorably. It can be seen from Table 2 that a wide variation in paint adhesion properties exists between leading hardboards on the market.

The pictorial results of the test shown in Fig. 11 illustrate how various treatments affect the paint adhesion properties of hardboard. The purpose here is to show how this device can be used as a research tool to develop new products with improved properties and as a development tool to improve manufacturing processes.

Limitations of the Test

The type of materials that can be successfully tested are limited to flat or slightly curved materials with sufficient internal bond and structural strength to withstand separation or failure (or both) within a maximum resistance range of 0.85 foot pound. This limitation is based on comparative data shown in Table 1, which clearly show that the 0.85 foot pound value is, according to other established tests, good to excellent adhesion. The straight line relationship of machine values to per cent failure does not exist, of course, when there is substrate failure within the 1.30 foot pounds resistance range.

It was found during the development of the test that a maximum separation value of only 0.75 foot pound at zero per cent paint failure could be obtained on some smooth surfaced finish coats such as enamels, varnishes and oil-base exterior paints. This, of course, indicates lack of adhesion and prohibits the testing of these finishes with the standard tape. Subsequent investigations have established, however, that tapes are available with improved adhesion and tensile strength, which will boost this separation value to the required range of 1.30 foot pounds at zero per cent paint failure, and thus place these finishes within the range of the test.

The cohesion failure of an automotive primer coat on cold rolled steel indicates that the 1.30 foot pounds of force per unit area being exerted is substantial, and is near that required to test lacquer finishes for cohesion as well as adhesion on sheet metal. Calibrated weights and tapes with improved adhesion are available that will increase the maximum energy output of the device to that well within the 2 to 4 foot pound range. For the present, the machine is restricted to the existing energy level, and will not measure adhesion beyond that point.

Conclusions

The detailed analysis of the performance characteristics in evaluating various undercoats to hardboards shows this device to be accurate and very simple to operate. The subjectiveness inherent in other common tests used for evaluating the adhesion of surface coatings to wood and modified wood products has been removed successfully with this device.

Further tests are being studied that involve surface coatings to wood products such as lumber siding, plywood, particle board, paper and plastic overlays, and so forth. The results have not as yet been analyzed, but it is felt that favorable results will be obtained. This device has other applications diverse from adhesion testing that make it a valuable tool to have in either the laboratory or the manufacturing plant.

An advantage of this device over other devices for measuring adhesion is that it can be used on wood products as well as other non-metallic and metallic materials with accurate results. Simplicity of operation as well as speed of operation are also advantages of importance.

Other Uses

Although this machine was developed for evaluating the adhesions of various surface coatings to wood products, it has many other possible applications.

The adhesion of various paints to metallic materials has been observed briefly and with encouraging results.

Although no work has been done on the test as related to the adhesion of surface coatings to non-metallic materials such as plastics, ceramics, fabrics, concrete, and so forth, the possibilities for such applications are good.

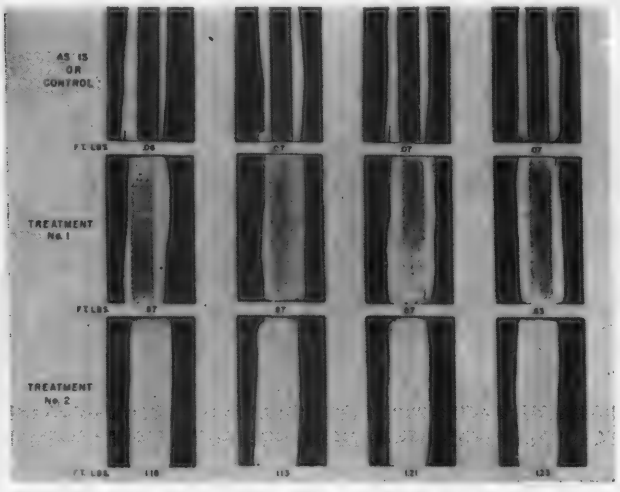


Fig. 11.—Results of correlation of machine values to per cent paint failure and the effect of treatment on adhesion (lacquer base coat).

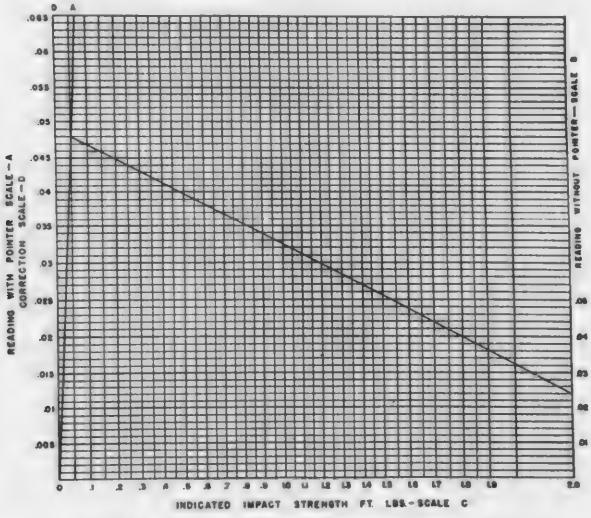

READING WITH POINTER SCALE—A CORRECTION SCALE—D
READING WITHOUT POINTER—SCALE B
INDICATED IMPACT STRENGTH FT. LBS.—SCALE C

Fig. 12.—Correction chart for windage and friction.

Bound-Water Diffusion into Wood in the Fiber Direction[1]

A. J. Stamm
Subject Matter Specialist, Forest Products Laboratory, Forest Service, U. S. Department of Agriculture[2]

Measurements were made of the diffusion of water in the fiber direction into wood, the voids of which had previously been filled with molten metal. Bound-water diffusion coefficients in the fiber direction are practically the same for all woods. The movement of water is controlled by the vapor pressure and consists of a series of molecular jumps rather than a mass liquid movement.

THE MOVEMENT OF WATER through wood has been previously shown to consist of a complicated combination of liquid flow and diffusion of water vapor through the coarse capillary structure and the diffusion of bound water through the wood substance (2,4,5,12,13).[3]

The author (12) has attempted to factor the combined movement theoretically into its component parts. To do so, a number of simplifying assumptions had to be made. It was assumed that the flow of water vapor through the communicating pit structure under pressure followed Poiseuille's law, as does the flow of liquids. This has recently been shown to be incorrect because the mean free path of molecules in the vapor is greater than the most probable capillary size of the pit structure.

It was also assumed that bound-water movement was a mass movement through transient capillaries within the cell walls on which a monomolecular layer of adsorbed water was fixed. Recent measurements of the movement of bound water through cellophane (15,16,17) have indicated that bound-water movement involves a series of jumps of one molecule at a time from one adsorption site to another. It thus is of importance to show whether this is true for wood and, if so, how it affects the previous theoretical analysis. A means was therefore sought for measuring the diffusion of bound water through wood substance that would be independent of vapor diffusion and free-water movement.

[1] Presented at Session XVI, General, FPRS 12th National Meeting, June 22–27, 1958, in Madison, Wis.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[3] Numbers in parentheses refer to the Literature Cited at the end of this report.

The Author: A. J. Stamm holds a BS from the California Institute of Technology, and MS and PhD degrees from the University of Wisconsin. He joined the US FPL in 1925.

WHAT THIS RESEARCH MEANS

Methods for the drying of wood have not changed significantly since the introduction of forced circulation and improved temperature and humidity control in dry kilns. This could be because we are approaching the ultimate in kiln drying practice, or more probably to the fact that we do not know enough about the mechanism of moisture movement in wood to make drastic improvement in the methods for its removal.

Three separate types of moisture movement are involved in the drying of wood. Because of their interrelationships, it has thus far been impossible to gain a thorough understanding of the phenomena involved. If conditions could be worked out that would allow only one type of movement to take place at a time, the problem could be greatly simplified. This paper describes such a method and presents data for the movement of bound water alone through wood.

Editor

Such data, when used in a reanalysis of the contribution of the different types of water movement, should ultimately be helpful in developing new methods for the drying and conditioning of wood.

Filling the Capillary Voids with Metal

A survey of various possible inert materials for filling the voids of wood so as to eliminate capillary and vapor movement in subsequent diffusion measurements indicated that absence of contraction upon solidification is of the greatest importance. Most molten materials occupy a volume that is 6 to 15 per cent greater than that of the corresponding solids. Even if the voids of wood could be completely impregnated with them, upon solidification some continuous capillary voids would still remain as a result of the contraction. It was hence decided to use an alloy of bismuth, tin, and lead (melting point 105° C.) that expands about 2 per cent in going from the liquid to the solid phase.

Preliminary tests indicated that sufficiently complete penetration of the voids of wood with molten metal could be accomplished only on small specimens under very high pressures. For this reason, all the data for metal-impregnated wood given in this report were obtained on cross sections ranging in thickness from 0.1 to 0.2 inch. The specimens were cut from straight-grained pieces of wood in which the annual rings were of minimum curvature and parallel to two opposite faces. The tangential and radial dimensions ranged from 1.5 to 2.0 inches. The end-grain surfaces were carefully sanded to remove all saw marks, scratches, and loose fibers. It will be shown later why this had to be done before, rather than after, impregnation with metal. The sections were then ovendried to constant weight, and the dimensions were determined with a dial gage.

The impregnation with molten metal was carried out in a high-pressure hydrogenation bomb 8 inches high by 3 inches in inside diameter. It was filled to a depth of about 2 inches with the molten metal and cooled. Ovendry cross sections were placed on the solid metal surface, and on top of them was placed a steel weight about 4 inches long by 1 inch in diameter. The bomb was sealed and placed inside a heating jacket. A thermocouple was inserted in the bomb wall. The temperature was raised to about 50° C., and the bomb was evacuated overnight to a pressure of 1 millimeter of mercury or less to remove air from the wood.

Next morning the temperature was raised to 125° to 130° C. to melt the metal in the bomb. The weight on the specimen caused it to become immersed in the molten metal, while evacuation was continued for another 3 to 4 hours. Air was then admitted, and an air pressure of 600 to 2,700 psi was applied and held until the next morning. The pressure was then released, and the bomb was removed from the heater and opened.

When the temperature had dropped to 110° C., the weight and the specimen were rapidly removed, and the surfaces and edges of the specimen were scraped quickly with a knife to remove surface metal. The specimen was cooled in a desiccator, weighed, and its dimensions determined. The dimensions were in all cases very close to the original ovendry dimensions, which indicated that the metal had not penetrated into the wood substance.

The extent to which the specimens were filled with metal was calculated as follows: The ovendry density of the wood, d_w, was calculated from its original weight and volumes, V, when ovendry. The theoretical fractional void volume, f, was calculated from

$$f = 1 - \frac{d_w}{1.46} \qquad 1)$$

where 1.46 is the density of dry wood substance. The density of the metal, d_m, was found to be 9.18 by water displacement. The theoretical weight of metal required to fill the voids of the wood was determined by

$$w_t = d_m V f \qquad 2)$$

The actual weight, w_a, of metal in the wood is the weight of the impregnated specimen minus the weight of the dry wood. The fraction of theoretical filling, determined by

$$F = \frac{w_a}{w_t} \qquad 3)$$

was found to range from 0.65 to 0.89.

Filling of the voids was thus far from complete. It did not vary greatly with species or consistently with thickness. Increasing the air pressure above 600 psi also had only a small effect. As some of the sections were below the average fiber length in thickness, little if any passage of metal through pit membrane pores was necessary. Since the metal does not tend to wet wood, it appeared that the incomplete penetration was because the molten metal receded from the finest capillaries when the air pressure was released.

To check this assumption, a treated section of southern pine sapwood was cooled to solidify the metal while still under pressure in the bomb. When the bomb was opened, it was carefully heated around the surface so that the metal weight and specimen could be removed. The specimen was cut free and sanded to its original thickness, and weighed. The fractional filling in this case was 0.925. A matched specimen impregnated under identical conditions but removed from the bomb and scraped while hot had a fractional filling of only 0.835.

To check this assumption further, a specimen in which the metal had been solidified under pressure was placed in an oven and heated to about 110° C. Little drops of molten metal appeared on the surface, demonstrating the tendency of the molten metal to back out of the finest capillaries where it had been forced under pressure. No exudation of metal occurred during heating of similar specimens that had been removed from the oven while still hot and then scraped.

The specimens that had been sanded after being filled with the metal had a mirror-like surface in contrast to the dull gray of the specimens that had been scraped while hot. Microscopic examination of the surface showed fine scratches that appeared to be continuous over filled lumen and fiber-end areas. Further sanding to significantly less than the original thickness did not change the continuous appearance of these surface scratches. It was therefore supposed that fine metal particles sanded away from the lumen ends became imbedded in the softer cell wall ends. This supposition was confirmed by the fact that diffusion measurements always gave lower and more variable diffusion coefficients for metal-filled specimens that were subsequently sanded than for those that were scraped while hot. It will be shown later that complete filling of the voids is not necessary to obtain reliable diffusion coefficients, provided there is no intercommunication between the remaining voids. Hence, the technique of scraping the surfaces of the metal-impregnated specimens while still hot was adopted to attain a uniformly clean surface, even though more complete filling could be obtained by the alternate technique.

Diffusion Under Liquid Contact Conditions

Measurements were made of the rate of takeup of water by the ovendry, metal-impregnated specimens when they were immersed to a depth of 1 centimeter in water. At definite intervals of time, the specimens were removed from the water, rapidly blotted to remove surface water, weighed measured, and replaced in the water The time that the specimens were out of the water for the measurements never exceeded 1 minute. This time was included in the soaking time, since diffusion continued even though the supply of water at the surface was momentarily cut off. It is believed that the error caused by interrupting the continuity of water supply for these short periods is small, because the diffusion coefficients for specimens frequently removed were quite similar to those for specimens infrequently removed from the water.

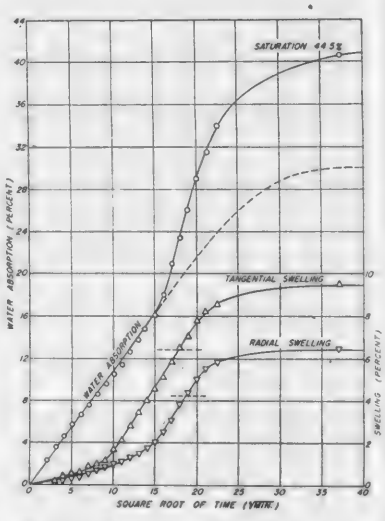


Fig. 1.—Rate of water absorption and swelling of a cross section of western hemlock 0.297 centimeter thick, with a specific gravity of 0.548 and impregnated with molten metal that filled 85 per cent of its void volume, when immersed in water at 25.5° C. The dashed extension of the linear portion of the water-absorption plot to the fiber saturation point was drawn from the point marking a moisture content equal to two-thirds of the fiber saturation point. Dashed horizontal lines intersect curves at two-thirds of the final swelling values.

In Fig. 1, the water absorption and the swelling of a western hemlock heartwood specimen are plotted against

the square root of the immersion time. The specimen, 0.297 centimeter thick, had been immersed in water at 25.5° C. The resulting curve shows that an initially linear relationship exists between the water absorption and the square root of time, followed by an increased rate of water absorption and then a decrease. Measurements of the rate of water absorption by both unimpregnated wood (1, 13) and cellophane (15, 17) show the same initial linear relationship and the same final decrease in the rate of water absorption, but they do not show the intermediate increase in rate. It has been shown that the initial linear relationship would be expected for all diffusion systems in which a parabolic bound-water gradient is set up in the solid up to the point at which water just reaches the center of the specimen (15, 17). Beyond this point, a decrease in rate would be expected. The initial and final parts of the relationship are hence normal. The increased rate of water absorption beyond the linear portion of the curve is believed to result because water entered voids not filled with metal. Since this can occur only by condensation, it does not occur until the cell walls adjacent to the voids have reached saturation. This explains why the break from the linear relationship was delayed. If it were not for the filling of these small discontinuous voids with water, water absorption would stop when the fiber saturation point was reached.

Table 1 gives data on the extent to which a series of cross sections of different species were filled with molten metal, the final equilibrium amounts of water actually taken up in the remaining voids, and the amounts that theoretically could have been taken up by the remaining voids. The amount actually taken up is the total equilibrium water takeup minus that required to bring the wood to the fiber saturation point per gram of wood. The fiber saturation point values used were taken from the literature (3,9,10,11). The theoretical weight of water that could be taken up by the portion of the voids not filled with metal per gram of wood was calculated from the following equation:

$$g = \frac{f}{d_w}(1 - F)\ d \qquad 4)$$

where d is the density of water and the other symbols have the same significance as in equations 1) and 3). In all cases, the actual takeup of water in the remaining voids is somewhat less than the theoretical value. The difference between them is greatest in cases where the filling of the sections with metal is least complete.

Table 1.—EXTENT TO WHICH CROSS SECTIONS OF VARIOUS SPECIES OF WOOD WERE FILLED WITH MOLTEN METAL, AND WATER TAKEUP BY REMAINING VOIDS

Species	Part of wood[1]	Fiber saturation point	Fraction of void volume filled with metal	Final water takeup by unfilled voids	
				Actual	Theoretical
		Per cent		Gram per gram	Gram per gram
Western hemlock	H	30	0.845	0.15	0.17
Western hemlock	H	--	.85	.15	.17
Western hemlock	H	--	.89	.11	.12
Sitka spruce	H	30	.88	.20	.23
Douglas-fir	H	30	.82	.11	.20
Southern pine	S	28	.835	.14	.20
Southern pine	S	--	.925[4]	.07	.09
Redwood	H	24	.68	.33	.50
Redwood	H	--	.87	.14	.21
Redwood	H	--	.80	.21	.32
Redwood, extracted	H	27[2]	.67	.33	.60
Redwood, extracted	H	--	.72	.24	.51
Paper birch	H	32[3]	.77	.17	.22
Sweetgrum	S	32[3]	.67	.29	.36
Sweetgum	S	--	.65	.33	.38
Black cottonwood	S	32[3]	.80	.35	.57
Black cottonwood	S	--	.90	.20	.27

[1]H, heartwood; S, sapwood.
[2]Calculated from the increase in swelling after extraction beyond that for the unextracted wood.
[3]Assumed to be the same as for basswood and maple.
[4]Cooled under pressure and sanded.

The plots of water absorption versus square root of time for the various runs made under water immersion conditions show that the upward break from the linear relationship occurs at lower moisture content levels when the filling of the sections with molten metal is least complete. In Fig. 1, the upward break for western hemlock 85 per cent filled with metal occurs at 16 per cent moisture content. For the extracted redwood that was only 67 per cent filled, the break occurred at 10 per cent moisture content. The sweetgum that was only 65 per cent filled also showed the break at 10 per cent moisture content. It is felt that this is about the lowest percentage of filling that will give an adequate initial straight line for calculating the diffusion coefficient.

It was shown in the study of the diffusion of water into cellophane (15,17) that the linear relationship of moisture content to the square root of time theoretically should and does extend to two-thirds of the final adsorption value before curving off to the right as a result of the parabolic character of the moisture gradients. Because the moisture gradients in wood are also parabolic (6,21), the same relationship should exist for wood if there were no remaining voids. The dashed curve of Fig. 1 has thus been drawn as an extension of the linear relationship of moisture content to the square root of time, curving to the right toward the fiber saturation point from a point two-thirds the value for the fiber saturation point.

Fig. 1 also gives the relationship between the swelling in both the tangential and radial directions and the square root of time. In both cases, swelling gradually increases until a linear relationship is obtained between swelling and the square root of time. This continues until two-thirds of the final swelling has occurred, at which point the curve swings to the right. This type of swelling curve has been previously shown to occur for water absorption by wood cross sections (14).

The reason for the slow initial development of swelling is that an appreciable amount of water has to be taken up by the wood before it can penetrate deeply enough in the fiber direction to cause swelling of the section as a whole at right angles to the direction of absorption. The break to the right, in both linear relationships, that occurs at two-thirds of the final value results because moisture has reached the center of the specimen under a parabolic gradient, as was shown to be the case for cellophane (15,17). The fact that this point for water absorption occurs at practically the same time as that for swelling is further justification for the way the dashed curve in Fig. 1 is drawn.

The diffusion coefficients, D, were calculated from the rate of water adsorption by means of the following equation:

$$D = \frac{\pi a^2 E_a^2}{16\ t} \qquad 5)$$

in which a is the thickness of the specimen and E_a is the moisture content attained in the time, t, expressed as a fraction of the final moisture content. When a is expressed in centimeters and t is in seconds, the diffusion coefficient is in centimeters squared per second. The derivation of this equation by Prager and Long (8) is based on a solution of Fick's general diffusion equation by Boltzman, who assumed that the material is an "infinitely thick solid" the surface of which instantly attains equilibrium condi-

ditions. This solution would be expected to hold up to a point where the concentration at the center of the specimen commences to change, since up to this point the thin specimen acts as an infinitely thick solid. This point has been shown by the author to occur when $E_a = 0.667$ for materials in which the moisture gradient is parabolic (15,17).

Equation 5) can also be used to calculate the diffusion coefficients from the swelling data at $E_a = 0.667$ (two-thirds of the final swelling) and the corresponding value of *t*.

Table 2 gives the diffusion coefficients for bound water passing in the fiber direction through cross sections of several species of wood that vary in thickness from 0.290 to 0.473 centimeter and in specific gravity from 0,284 to 0.616, and which were impregnated with the molten metal so as to fill from 65 to 89 per cent of the void volume. The table shows that diffusion coefficients calculated from the rate of water adsorption and from the swelling are in substantial agreement. The values for the different softwoods, exclusive of redwood, all fall within the range of $39 \pm 5 \times 10^{-8}$ square centimeter per second, irrespective of variations in extent of filling and variations in thickness and specific gravity of 50 per cent.

The reason why *D* is independent of thickness and density of the wood is that the former is accounted for in the term a^2 and the latter in the term *E* of equation 5). Any differences between the values of *D* for sapwood and heartwood also fall within the range of $39 \pm 5 \times 10^{-8}$ square centimeter per second. Sufficient data have not been obtained for a statistical analysis, but is appears that a large part of the variation can be considered to be experimental error.

Unextracted redwood gave diffusion coefficients about twice as large as those for the other softwoods. This was believed to be due to the large amount of water-soluble extractive in the wood—an assumption confirmed by the fact that extraction with warm water at 35° C. for a week, during which a 10 per cent weight loss occurred, reduced the diffusion coefficients to values near those for the other softwoods. The high values for the unextracted redwood are undoubtedly due to the fact that the extractives bulk the fiber and act as though some moisture were originally present when the measurements were begun. This will be shown to be the case.

Table 2 also gives the diffusion coefficients for paper birch heartwood and sweetgum and black cottonwood sapwood. The values obtained from both the water absorption and the swelling data are again very similar. The values all fall within the range of $46 \pm 7 \times 10^{-8}$ square centimeter per second. The hardwoods thus appear to have diffusion coefficients that are, on the average, about 18 per cent higher than those for the softwoods. No really significant difference seems to exist between heartwood and sapwood. Neither are the differences of 80 per cent in thickness and over 100 per cent in specific gravity very significant, since these variables are accounted for in equation 5). The fact that no consistent decrease in the diffusion coefficient occurs with an increase in the degree of filling of the voids with molten metal is good evidence that no continuous voids that extend to the surface remain in the wood.

Table 2.—DIFFUSION COEFFICIENT FOR BOUND WATER THROUGH THE WOOD SUBSTANCE OF SEVERAL SPECIES IN THE FIBER DIRECTION, WHEN IMMERSED IN WATER AT 25.5° C.

Species	Part of wood[1]	Thickness of specimen Cm.	Specific gravity of wood[2]	Diffusion coefficients at two-thirds saturation	
				Based on weight increase Cm.²/sec.x10⁸	Based on swelling Cm.²/sec.x10⁸
Western hemlock	H	0.427	0.557	42.5	44
Western hemlock	H	.297	.548	36.5	38
Western hemlock	H	.290	.554	40	40
Sitka spruce	H	.292	.377	37	33.5
Douglas-fir	H	.376	.550	41	43
Southern pine	S	.346	.531	36	41
Redwood	H	.302	.444	92	92
Redwood	H	.376	.440	88	78
Redwood	H	.328	.432	90	79
Redwood, extracted	H	.310	.396	55	54
Redwood, extracted	H	.440	.399	49	58
Paper birch	H	.346	.616	43.5	39
Sweetgum	S	.473	.519	44	45
Sweetgum	S	.394	.565	43	47
Black cottonwood	S	.259	.284	47	46
Black cottonwood	S	.340	.293	51	53

[1]H, heartwood; S, sapwood.
[2]Based on weight and volume of ovendry wood.

Effect of Temperature

The rates of water absorption and swelling of metal-impregnated cross sections of Sitka spruce immersed in water were measured at four different temperatures. From 81 to 88 per cent of the voids in these specimens had been filled with metal.

The data are given in Table 3. The increase in the diffusion coefficients with increasing temperature is shown to be about in proportion to the increase in vapor pressure of water. The product that results when the square of the slopes of the plots of moisture content versus square root of time is multiplied by the square of the thickness of the specimens also varies with temperature about as much as does the vapor pressure of water. This is similar to what was found for cellophane (15, 17). When the logarithms of the diffusion coefficients were plotted against the reciprocal of the absolute temperature, a straight line resulted, which indicates that the process of bound-water diffusion is an activated one. The activation energy calculated from this relationship is 12,000 calories per mole of water adsorbed. This is lower than the activation energy for true chemical reactions, but in the range expected for water being held by hydrogen bonding.

Bound Water Diffusion Under Different Relative Humidity Conditions

Measurements were made of the rate of water vapor adsorption and swelling on thin cross sections of ovendry Sitka spruce impregnated with molten metal to the extent of 81 to 86

Table 3.—EFFECT OF TEMPERATURE UPON THE BOUND-WATER DIFFUSION INTO METAL-IMPREGNATED CROSS SECTIONS OF SITKA SPRUCE IN THE FIBER DIRECTION

Temperature	Vapor pressure water	$\frac{(aM)^2}{t}$[1]	Fiber saturation point[2]	Diffusion coefficient at two-thirds of saturation	Ratio of values for two adjacent temperatures		
		Cm.²		Cm.²	Vapor pressure	$\frac{(aM)^2}{t}$	Diffusion coefficients
°C.	Mm Hg	sec.	Per cent	$\frac{}{\text{sec.}} \times 10^8$			
3.5	5.89	0.0268	32.2	9			
					0.241	0.248	0.23
25.5	24.47	.108	30.0	39			
					.466	.495	.44
39.0	52.44	.218	28.7	88			
					.413	.501	.44
56.5	126.8	.435	26.9	198			

[1]Thickness times moisture content squared divided by time.
[2]On basis of fiber saturation point being lowered 0.1 per cent for each degree Centigrade increase in temperature (19). This was substantiated from the decrease in swelling with an increase in temperature.

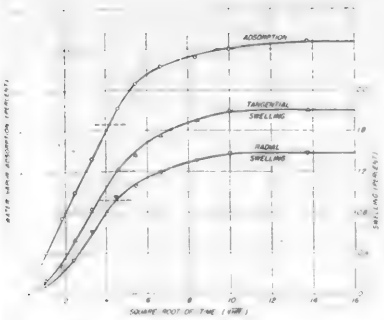


Fig. 2.—Rate of water adsorption and swelling of a cross section of Sitka spruce 0.285 centimeter thick, with a specific gravity of 0.332 and impregnated with enough molten metal to fill 83 per cent of its void volume, when exposed 2 feet from a fan in an atmosphere controlled at 80 ± 1 per cent relative humidity and 26.7° C. Dashed horizontal lines intersect curves at the points where two-thirds of the final water adsorption and swelling had taken place.

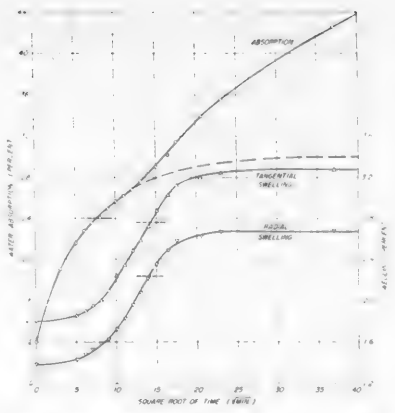


Fig. 3.—Rate of water absorption and swelling of a metal-impregnated Sitka spruce specimen 0.285 centimeter thick when immersed in water at 25.5° C. after obtaining equilibrium with 80 per cent relative humidity. The wood, which had a specific gravity of 0.332, contained enough metal to fill 83 per cent of its void volume. Dashed extension of the absorption curve drawn to the fiber saturation point. Dashed horizontal lines intersect curves at the points were two-thirds of the theoretical water absorption and actual swelling had taken place.

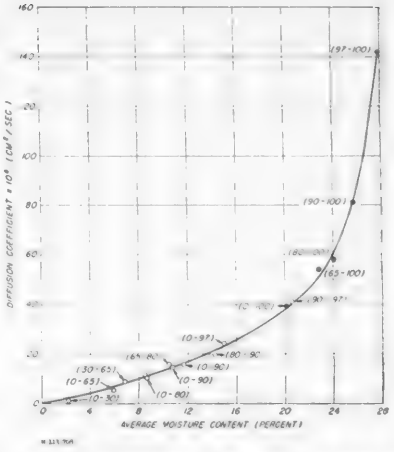


Fig. 4.—Bound-water diffusion coefficients in the fiber direction through the wood substance of Sitka spruce, as related to average moisture content (initial moisture content plus two-thirds of moisture-content increase). Numbers in parentheses indicate the relative humidity at which the specimen was originally in equilibrium and the relative humidity at which the measurements were made. The value 100 represents soaking in water. Open points represent averages of the diffusion coefficients calculated from both water-adsorption and swelling data. Shaded points represent the diffusion coefficients calculated from swelling data only.

per cent of their void volume, when exposed to one of five different levels of relative humidity, when moved from one humidity condition to another, and when immersed in water after being exposed to the atmosphere at a controlled humidity. The relative humidity conditions were periodically checked during the course of the measurements with an electric hygrometer and were found to be within ± 1 per cent absolute of the recorded values. The temperature was in each case 80° F. ± 1° F. (26.7° C.).

Fig. 2 gives the rate of water vapor adsorption and swelling of an oven-dry specimen placed 2 feet in front of a circulating fan in an atmosphere with 80 per cent relative humidity. There is no upward break of the linear curve for water adsorption plotted against the square root of time, such as had been found for water immersion (Fig. 1) prior to the characteristic decrease. This indicates that no water vapor condensed in the voids that do not contain metal. This was true for adsorption in air at all levels of relative humidity used, including 97 per cent.

Dashed horizontal lines were drawn in Fig. 2 at two-thirds of the final adsorption and swelling values. These cross the plots at about the point where the linear relationships end and occur at practically the same time. The diffusion coefficients calculated at two-thirds of the final moisture adsorption, 8.6 per cent, are 10.9 x 10^{-8} square centimeter per second on the basis of water vapor adsorption, 9.7 x 10^{-8} square centimeter per second on the basis of tangential swelling, and 10.2 x 10^{-8} square centimeter per second on the basis of radial swelling. This is typical of the order of agreement between the diffusion coefficients calculated from the three different measurements when water immersion is not involved.

Fig. 3 gives the data obtained for the specimen of Fig. 2 when it was immersed in water at 25.5° C. after being in equilibrium with 80 per cent relative humidity. The initial linear relationship between moisture content and square root of time shown in Figs. 1 and 2 is not obtained for such specimens in water. Evidently, water enters voids near the surface almost immediately when absorption begins in a specimen at a uniform moisture content of 12 per cent. Later on, inner voids become accessible, which accounts for the inflection in the curve.

Quite similar curves were obtained for specimens going from 65, 90, and 97 per cent relative humidity into water. It is thus evident from the data that diffusion coefficients cannot be calculated from the adsorption data. The swelling curves are, however, quite normal. Diffusion coefficients calculated from the times at which two-thirds of the swelling changes have occurred (indicated by the dashed horizontal lines) were 57 x 10^{-8} square centimeter per second for tangential swelling and 58 x 10^{-8} square centimeter per second for radial swelling. These correspond to an average moisture content of 24 per cent (12 + 2/3 [30–12]).

Fig. 4 gives a plot of the diffusion coefficients for specimens at different levels of average moisture content (initial + 2/3 of moisture-content change). The relative humidities between which the various points have been obtained are given in parentheses beside each point. Immersion in water is represented by 100. The bound-water diffusion coefficients are shown to increase rapidly in an exponential fashion with an increase in moisture content. The same sort of increase was found for cellophane (16, 17). Long and associates (7, 8) have also found that the diffusion coefficients of liquids other than water increase exponentially with liquid content in various synthetic-polymer membranes.

It is possible to estimate the effect of the extractives in redwood upon the diffusion coefficient from Fig. 4 if it is assumed that the extractives act like initially present water. Unextracted redwood, which was found to have an average bound water diffusion coefficient of 86 x 10^{-8} square centimeter per second (Table 2), should, judging from the data of Fig. 4, have an apparent average moisture content of 26 per cent (actual moisture plus extractive content, assuming that the extractives have a specific gravity of 1). This would result from a theoretical bulking extractive content of 18 per cent

(2/3 [30–18] + 18). Similarly, redwood that lost 10 per cent of its weight on extraction and had an average diffusion coefficient of 54 x 10^{-8} square centimeter per second (Table 2), should have an average apparent moisture content of 23 per cent. This would result from a theoretical bulking extractive content of 9 per cent (2/3 [30–9] + 9). Thus, a loss of 9 per cent of extractive (18–9) would account for the difference between experimental diffusion coefficients. The actual loss was 10 per cent.

Conclusions

It is shown that impregnation of wood cross sections with a molten metal that expands slightly upon solidification need not be complete to permit calculation of bound-water diffusion constants in the fiber direction from water-absorption data. This is because water can enter the discrete voids only when the adjacent fibers have reached saturation. An initial linear relationship between the moisture content and the square root of time is hence obtained that results entirely from bound-water adsorption by the cell walls. The increased rate of water absorption obtained on water immersion following the intial linear relationship is shown to result because the voids not filled with metal take up appreciable amounts of water. This does not happen when the specimens are exposed to water vapor in controlled atmosphere, because saturation of the fibers is never reached.

Bound-water diffusion coefficients determined under water-immersion conditions are independent of thickness of the specimens and their specific gravity, since these variables are accounted for in the terms a^2 and E of the diffusion equation. They vary but slightly between species for woods with a low content of water-soluble extractives. The values for redwood are high as a result of its high content of water-soluble extractive, to an extent that can be accoutned for on the basis of the bulking action of the extractives on the cell wall. The diffusion coefficients are practically the same for heartwood and sapwood, and only slightly higher for hardwoods than for softwoods.

The bound-water diffusion coefficients increase with an increase in temperature in the same manner as the increase in vapor pressure of water, as was found to be the case for cellophane (15, 17). This would be expected if the takeup of water at the surface were dependent upon the frequency of impact of the wood surface with high-energy molecules and the inward diffusion resulted from the jump of single molecules of water from one adsorption site to another of greater attractive force. It is hence believed that water moves into the wood in this molecular-jump fashion rather than as a continuous phase.

The fact that the logarithm of the diffusion coefficients varies as the reciprocal of the absolute temperature indicates that the diffusion is of the activated type. The activation energy, 12,000 calories per mole of water adsorbed, is of the order expected if water is held by hydrogen bonding. Data for the heat of adsorption (19) and for swelling in different liquids (20) have previously indicated that water is probably held by hydrogen bonding.

Data for the adsorption of water vapor by metal-impregnated cross sections under different relative humidity conditions have shown that the bound-water diffusion coefficient in the fiber direction increases in an exponential manner with an increase in the average moisture content of the wood. Such an increase would be expected as a result of the parabolic moisture gradient (15, 17). A much smaller moisture-content change per unit distance into the wood occurs at the higher than at the lower levels of moisture content, which indicates that moisture moves more readily when wood is at a high than at a low moisture content (15, 17). Each adsorption site in wood can on the average, it is believed, hold up to six molecules of water (18), each succeeding molecule being held at a greater distance from the adsorption site, and with an exponentially decreasing force. It should thus be far easier for the fifth molecule to be desorbed from adsorption site 1 and be readsorbed as the fourth molecule on site 2 than for the second molecule on site 1 to be desorbed and again adsorbed as the first molecule on site 2. The electrical conductivity of wood has also been shown to increase exponentially with an increase in moisture content (11). This would be expected if the conductivity is proportional to molecular mobility.

The continuous diffusion coefficient experimentally established for bound water diffusing in the fiber direction is about half of the earlier estimated theoretical value (12).

Preliminary measurements of the combined diffusion of water vapor and bound water in the fiber direction indicate that only about 0.01 of the combined diffusion in the fiber direction is continuous bound-water diffusion. In the transverse directions it is expected that bound-water diffusion will account for a far larger proportion of the total moisture movement.

Literature Cited

1. Bateman, E., J. P. Hohf, and A. J. Stamm. 1939. Unidirectional drying of wood. Ind. Eng. Chem. 31, 1150–1154.
2. Burr, H. K., and A. J. Stamm. 1947. Diffusion in wood. J. Phys. Colloid Chem. 51, 240–261.
3. Higgins, N. C. 1957. The equilibrium moisture content-relative humidity relationship of selected native and foreign woods. Forest Prod. J. 7 (10): 371–377.
4. Hawley, L. F. 1931. Wood-liquid relations. U. S. Dept. Agr. Tech. Bull. No. 248.
5. Kollmann, F. 1951. Technologie des Holzes und der Holzwerkstoffe, 2nd ed., 443–494, Springer-Verlag, Berlin.
6. Martley, J. F. 1926. Moisture movement through wood. The steady state. Dept. Sci. Ind. Res. (Gt. Brit.), Forest Prod. Res. Tech. Paper 2.
7. Kokes, R. J., and F. A. Long. 1953. Diffusion of organic vapors into polyvinyl acetate. J. Am. Chem. Soc. 75, 6141–6146.
8. Prager, S., and F. A. Long. 1951. Diffusion of hydrocarbons in polyisobutylene. J. Am. Chem. Soc. 73, 4072–4075.
9. Seborg, C. O., F. A. Simmonds, and P. K. Baird. 1936. Sorption of water vapor by papermaking materials. Ind. Eng. Chem. 28, 1245–1250.
10. Spalt, H. A. 1957. The sorption of water vapor by domestic and tropical woods. Forest Prod. J. 7 (10): 331–335.
11. Stamm, A. J. 1929. The fiber-saturation point of wood as obtained from electrical conductivity measurements. Ind. Eng. Chem., Anal. Ed. 1: 94–97.
12. Stamm, A. J. 1946. Passage of liquids, vapors, and dissolved materials through softwoods. U. S. Dept. Agr., Tech. Bull. No. 929, 1–80.
13. Stamm, A. J. 1953. Diffusion and penetration mechanism of liquids into wood. Pulp and Paper Mag. Canada 54 (2): 54–63.
14. Stamm, A. J. 1955. Swelling of wood and fiberboards in liquid ammonia. Forest Prod. J. 5 (6): 413–416.
15. Stamm, A. J. 1956. Diffusion of water into uncoated cellophane. I. From rates of water vapor adsorption and liquid water absorption. J. Phys. Chem. 60: 76–82. Corrections 1671.
16. Stamm, A. J. 1956. Diffusion of water into uncoated cellophane. II. From steady state diffusion measurements. J. Phys. Chem. 60: 83–86. Corrections 1671.
17. Stamm, A. J. 1956. Diffusion in cellulosic materials. Australia Pulp and Paper Ind. Tech. Assoc. Proc. 10: 244–270.
18. Stamm, A. J. 1957. Adsorption in swelling versus nonswelling systems Tech. Assoc. Pulp and Paper Ind. 40 (9): 761–770.
19. Stamm, A. J., and W. K. Loughborough. 1935. Thermodynamics of the swelling of wood. J. Phys. Chem. 39 121–132.
20. Stamm, A. J., and H. Tarkow. 1950 Penetration of cellulose fibers. J. Phys and Colloid Chem. 54: 745–753.
21. Tuttle, F. 1925. A mathematical theor of the drying of wood. J. Franklin Inst. 200: 609–614.

Electrical Resistance Strain Gages

THEIR ZERO SHIFT WHEN BONDED TO WOOD [1]

ALAN SLIKER
Instructor, Department of Forest Products, Michigan State University, East Lansing

Experiments were designed to evaluate factors that influence zero shift of these gages in the interval following their being energized in the electrical measuring circuit. Drifts, caused by heat generated by currents in the gages, were studied with respect to type of substrate, emc of wood substrates, and current magnitude and heat dissipation of the gages.

ELECTRICAL RESISTANCE STRAIN GAGES hold promise of providing a better and more convenient method of strain analysis of wood than has heretofore been available. They have become very useful tools in the solutions of strain problems on metals, and their use has been extended to other materials with more or less success. Their accurate applications for analysis of stresses and strains in wood are particularly difficult to make, however, because of problems related to the nature of wood.

A few studies have already been made on the performance characteristics of these gages on wood. Some investigations concerned strain gage circuitry and gage design (2, 8, 9)[2]. Another group of studies (3, 5) involved work with gages in creep tests on dry and green lumber, and still other studies noted the comparisons between mechanical and electrical gages on wood (10, 11). In one of the latter studies, Solvey and Belcher concluded from their experiments on plywood that electrical resistance strain gages are more accurate than mechanical gages "at least as far as consistency of results is concerned." In a similar study, Noren (7) could detect no significant difference between compression measurements made with Huggenberger gages and Gustafsson's wire strain gages.

The purpose of this report is to discuss one quite common problem with electrical resistance strain gages on wood—zero shift of the gage. This phenomenon refers to the change in resistance of a gage that occurs where there has been no change in the forces applied to its test object.

On metals, zero shift can be caused by exposure of the gages to moisture or by the non-recovery of a zero gage reading after a test material is loaded and unloaded below its proportional limit. This report will cover another factor that causes zero shift in wood—thermal drift of the gages resulting from heat generated in the energized gage wires.

WHAT THIS RESEARCH MEANS

Bonded electrical resistance strain gages are one of the few types of gages that can be used to measure strain in microinches per inch. Because of the nature of wood, however, special precautions have to be taken for their most accurate use on this material.

This paper discusses problems encountered from the heat concentration in some of the more commonly used gages. Suggestions are made as to how this source of error in measurements may be minimized. Such information should make improved strain analysis studies on wood possible, particularly where small increments of strain are being measured as in determining Poisson's ratios and obtaining creep data.

Editor

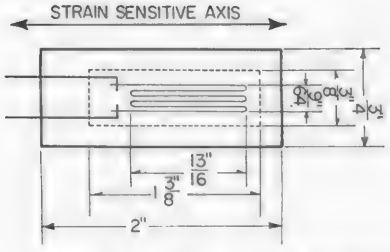


Fig. 1.—SR-4 type A-1 bonded wire electrical resistance strain gage manufactured by the Baldwin-Lima-Hamilton Corp. This is a 120-ohm, flat grid type gage made with a paper base, constantan wire, and nitrocellulose adhesive. All the grid wire is in the same plane in the gage.

Procedure

In the experiments for this report, three types of gages were used, SR-4 types A-1 and A-7 manufactured by the Baldwin-Lima-Hamilton Corp. and a specially constructed gage that will be described later (Figs. 1, 2, and 3). These gages were mounted on various substrates, as mentioned in each experiment, with a nitro-cellulose adhesive according to the recommendations of the gage manufacturer.

All drift measurements were made with a Baldwin Static Strain Indicator Type M with an AC power supply. This strain indicator has two external arms of its Wheatstone bridge circuit available for attaching strain gages. One arm is used for attaching the gage measuring strains and is called the active arm. The other external arm is commonly used for attaching a gage mounted on a specimen similar to the one under the active gage in order to

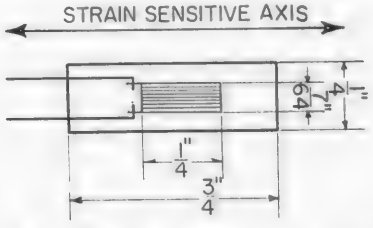


Fig. 2.—SR-4 type A-7 bonded wire electrical resistance strain gage manufactured by the Baldwin-Lima-Hamilton Corp. This is a 120-ohm wrap-around type of gage made with a paper base, constantan wire, and nitro-cellulose adhesive. The strain-sensitive wire in the gage is wrapped in a tight helix around a core of paper.

[1] 1958 Wood Award entry. Part of the work was done at the State University of New York College of Forestry and part at Michigan State U.

[2] Numbers in parentheses refer to the Literature Cited at the end of this paper.

[3] A complete copy of thie report, including 59 literature citations, is available on request from the FPRS National Office.

The Author: Alan Sliker holds BS and MF degrees from Duke University, and a PhD from the State University of New York College of Forestry. Before joining Michigan State three years ago, he worked at the US FPL.

cancel strains arising from such sources as temperature changes of test materials; this is called the compensating arm of the circuit. Except when stated otherwise, 120 ohm single-strand lengths of constantan wire were suspended in air in the compensating arm of the strain indicator circuit. These wires had no inherent drift properties and thus would not compensate any drifts of the test gages. When 120 ohm gages were in the measuring arm, there were 2 RMS volts across each gage.

Thermal drifts are recorded as the strain readings shown by the test gages versus the time they have been energized in the measuring circuit. To have time to balance the strain indicator bridge, all drift measurements were started 30 seconds after the strain indicator was turned on. The reading at 30 seconds was taken as the reference point from which to determine the amount of drift at following intervals of time as shown in Tables 1 through 4. This does not mean, however, that drift did not occur during the first 30 seconds: indeed, while the strain indicator was being balanced during this period, the maximum rate of drift was often observed.

Unmounted Gages and Those Mounted on Several Types of Substrates: SR-4 type A-7 gages were mounted on steel, plexiglass, and two blocks of basswood in order to evaluate the manner in which properties of the substrate materials would influence the warming drifts. The A-7 gage on one block of wood was mounted with its strain-sensitive axis perpendicular to the grain, and the A-7 gage on the other block had its strain-sensitive axis parallel to the grain. In addition, two A-7 gages were left unmounted for making drift measurements.

The gage mounted perpendicular to the grain on basswood and one unmounted gage were placed in a container with desiccant where the e.m.c. of wood was about 2 per cent at 76° ± 1°F. The remaining unmounted gage and those mounted on wood, plexiglass, and steel were kept in a conditioning room where the relative humidity was 50 per cent and the temperature was 76° ± 1°F.

Gages Mounted on Wood at Three Equilibrium Moisture Contents: Six SR-4 type A-1 strain gages were mounted on the tangential surfaces of basswood blocks with their strain-sensitive axes oriented perpendicular to the grain (Fig. 4). Two samples were kept at 4.6 per cent, two at 9.1 per cent, and two at 19.5 per cent e.m.c. for the basswood. Temperature during conditioning and testing of specimens was 88° ± 1°F.

After the drifts of the individual gages were recorded, the one mil constantan wire in the compensating arm of the measuring circuit was replaced by one A-1 gage at each moisture content condition while its paired gage was in the active arm. This was done to indicate the accuracy of drift measurements for individual gages and to

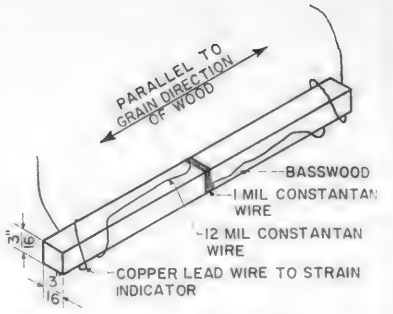


Fig. 3.—One-mil constantan wire wound with narrow spacing between adjacent strands around basswood base for the measurement of drift from the warming up of electrical resistance strain gages made from different adhesives.

Table 1.—WARMING DRIFTS OF COMMERCIAL SR-4 TYPE A-7 BONDED WIRE ELECTRICAL RESISTANCE STRAIN GAGES WITH SEVERAL SUBSTRATE MATERIALS

Duration of energizing current, in minutes	Warming drift in microinches/inch[1 2 3 4]: Unmounted gage in atmosphere of 50% R.H.	Unmounted gage in dry atmosphere	Gage mounted[5] parallel to grain on basswood in atmosphere of 50% R.H.	Gage mounted[5] perpendicular to grain on basswood in dry atmosphere	Gage mounted[5] on plexiglass in atmosphere of 50% R.H.	Gage mounted[5] on steel in atmosphere of 50% R.H.
½	0	0	0	0	0	0
1	40	16	43	+39	+27	0
2	95	−23	−105	+58	+42	−1
3	−135	−30	−152	+60	+47	−1
4	164	−32	−195	+57	+43	−1
5	187	32	−222	+52	+41	−1
6	−204	−32	−246	+49	+39	−1
7	219	33	−278	+44	+32	−1
8	−230	−33	−287	+42	+29	−2
9	−238	−32	−305	+41	+23	0
10	−244	−32	−319	+41	+20	−1

[1]Temperature during testing was 76° ± 1° F.
[2]A voltage of 2 RMS volts was across the 120-ohm gages during the test period.
[3]A 120-ohm length of one mil constantan wire was suspended in air in the compensating arm of the measuring circuit.
[4]Drift values are the total changes in strain indicated by the gages from the ½ minute measurement to each designated minute of the 10-minute measuring period. Minus sign before strain values indicates shortening of gage length; plus sign indicates an increase of gage length or tensile strain.
[5]Mounted with a nitro-cellulose adhesive.

Table 2.—WARMING DRIFTS OF COMMERCIAL SR-4 TYPE A-1 BONDED WIRE ELECTRICAL RESISTANCE STRAIN GAGES MOUNTED[1] PERPENDICULAR TO THE GRAIN ON BASSWOOD AT THREE EQUILIBRIUM MOISTURE CONTENTS

e.m.c. of basswood substrate	Gage in compensating arm of strain measuring circuit	Active gage in strain measuring circuit	Row design-nation	Warming drift in microinches/inch at indicated duration of energizing current in minutes[2 3 4]: ½	1	2	3	4	5	6	7	10	20	30	40	50	60
4.6%	120 ohm constantan wire[5]	Sample 1.	A	0	+13		+45	+50	+50	+52	+50	+41	−10	−56	−97	−129	−159
		Sample 2.	B	0	+16	+35	+46	+50	+55	+57	+57	+50		−9	−37	−64	−81
	(Row A—Row B)		C	0	3		1	0	5	5	7	9		47	60	65	78
	Sample 2.	Sample 1.	D	0	+ 2	+ 4	+ 5	+ 2	+ 1	+ 1	0	8	30	51	64	78	90
9.1%	120 ohm constantin wire[5]	Sample 1.	E	0	+17	+31	+33	+30	+21	+10	6	67	−203	−334	−449	539	618
		Sample 2.	F	0	+16	+28	+30	+25	+15	+ 5	11	52	−204	−338	−453	543	625
	(Row E—Row F)		G	0	+ 1	+ 3	+ 3	+ 5	+ 6	+ 5	+ 5	15	+ 1	+ 4	+ 4	+ 4	+ 7
	Sample 2.	Sample 1.	H	0	0	+ 2	+ 8	+10	+12	+16	+ 18	+ 21	+ 28	+ 28	+ 28	+ 27	+ 21
19.5%	120 ohm constantan wire[5]	Sample 1.	I	0	+ 9	+10	0	13	31	52	72	138	−354	−553	−738	901	1052
		Sample 2.	J	0	+ 6	+ 2	15	34	55	80	102	183	453	702	902	1063	1231
	(Row I—Row J)		K	0	+ 3	+ 8	+15	+21	+24	+28	+ 30	+ 45	+ 99	+149	+164	+ 162	+ 179
	Sample 2.	Sample 1.	L	0	+ 1	+ 2	+ 4	10	+12	+14	+ 19	+ 29	52	+ 72	+ 92	+ 106	+ 120

[1]Gages mounted with a nitro-cellulose adhesive.
[2]Temperature during testing was 88° ± 1° F.
[3]A voltage of 2 RMS volts was across each 120-ohm gage during tests.
[4]Drift values are the total changes in strain indicated by the gages from the ½ minute measurement to each designated minute of the 60-minute measuring period. Minus sign before strain values indicates shortening of gage length; plus sign indicates an increase of gage length or tensile strain.
[5]Single strand of one mil constantan wire having 120-ohm resistance. Wire was suspended in air between circuit terminals so that it would have no inherent drift.

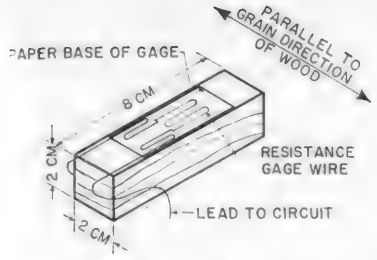


Fig. 4.—SR-4 type A-1 gage mounted on tangential surface of two by two by eight centimeter block of basswood for making drift measurements. Gage was covered with microcrystalline wax and placed in sealed container over salt solution at a constant temperature.

determine how well gages might compensate each other under identical conditions. Strains shown by the strain indicator were differences in drifts of paired gages.

In addition, to obtain an indication of the gages' behavior over long periods of activation, the drift of one gage was observed for 32 hours.

Gages Mounted on Wood at Two Angles to the Grain: To observe the effect of grain angle on drift, gages were glued on the tangential surfaces of flat-sawn pieces of basswood. Two gages, an SR-4 type A-7 and an SR-4 type A-1, were glued to the wood parallel to the grain, and also one of each gage type was applied perpendicular to the grain. Basswood was maintained at 5 per cent e.m.c., and temperature during testing was kept at 75° ± 1°F.

Gages Covered and Not Covered with Aluminum Foil at Four Current Levels: For this experiment, a special strain gage was made that consisted of a 120-ohm length of one mil constantan wire wrapped perpendicular to the grain around a basswood stick 3/16 inch square in cross-section. In all, seven turns of gage wire were spaced 0.27 mm. apart around the basswood. Short lengths of 12 mil constantan wire were soldered at the ends of the gage for lead attachments. A coating of nitro-cellulose cement was applied to the basswood before and after the gage was formed. (See Fig. 3.)

Voltages across the gages and thus the currents in them were controlled by placing appropriate resistors in series with gages in the external arms of the Wheatstone bridge. Resistances used were 120 ohms, 60 ohms, and 0 ohms, which were produced by parallel combinations of 120-ohm lengths of one mil constantan wire. Resistors used between the compensating terminals consisted of similar lengths of one mil constantian wire. Total resistance in the compensating arm was equal to the total resistance in the measuring arm of the strain gage bridge.

Since the test gage was in most cases only a part of the total resistance in the measuring arm, readings from the strain indicator dial had to be multiplied by an appropriate factor. Strains shown by the strain indicator were therefore multiplied by two when 120 ohms was in series with the test gage, by three halves when 60 ohms was in series with the test gage, and by five quarters when 30 ohms was in series with the test gage. Voltages across the measuring arm varied from 2 RMS volts when the resistance in the arm was 120 ohms to 2.10 RMS volts for 240 ohms in the arm.

A piece of aluminum foil one mil thick was wrapped around the gage, and drift at each test current was recorded again.

Dry bulb temperature during tests was 88° ± 1°F and wet bulb reading was 76° ± 1°F. Basswood was at 8 per cent e.m.c. Twenty-four hours elapsed between successive measurements.

Table 3.—WARMING DRIFTS OF COMMERCIAL SR-4 TYPE A-1 AND A-7 BONDED WIRE ELECTRICAL RESISTANCE STRAIN GAGES MOUNTED PARALLEL AND PERPENDICULAR TO THE GRAIN ON BASSWOOD AT 5% E.M.C.

	Warming drift in microinches/inch[1] [2] [3] [4]			
	SR-4 Type A-1 gages		SR-7 Type A-7 gages	
Duration of energizing current, minutes	Mounted[5] parallel to grain	Mounted[5] perpendicular to grain	Mounted[5] parallel to grain	Mounted[5] perpendicular to grain
½	0	0	0	0
1	— 2	+ 4	— 36	+ 9
2	—10	+10	— 77	+ 2
3	—12	+10	—109	— 17
4	—16	+ 9	—138	— 37
5	—21	+ 8	—159	— 65
6	—22	+ 2	—179	— 88
7	—24	0	—198	—112
8	—26	— 2	—211	—132
9	—31	— 5	—228	—152
10	32	10	239	176
25	----	----	—339	—399
30	----	----	—359	—465

[1]Temperature during testing was 75° ± 1° F.
[2]A voltage of 2 RMS volts was across the 120-ohm gage during the test period.
[3]A 120-ohm length of one mil constantan wire was suspended in air in the compensating arm of the measuring circuit.
[4]Drift values are the total changes in strain indicated by the gages from the ½ minute measurement to each designated minute of the measuring period. Minus sign before strain values indicates shortening of gage length; plus sign indicates an increase of gage length or tensile strain.
[5]Mounted with a nitro-cellulose adhesive.

Results and Discussion of Results

Unmounted Gages and Those Mounted on Several Types of Substrates: Drifts of SR-4 type A-7 gages that were unmounted and the ones on different types of substrates were taken at regular intervals of time as recorded in Table 1.

Gages mounted on the various substrates displayed different magnitudes of drift than did the unmounted gages, thus showing that the physical properties of the substrate are very important as far as stability of gages is concerned. For instance, the SR-4 type A-7 gage mounted on steel in 50 per cent relative humidity atmosphere showed no drift at all compared to the −244 microinches per inch displayed by the unmounted gage in the same atmosphere. Two probable reasons for the gage's stability on steel are the rigidity of steel and its high thermal conductivity. The former would prevent the gage from changing its di-

Table 4.—WARMING DRIFT FOR FOUR MAGNITUDES OF ENERGIZING CURRENT ON BONDED WIRE ELECTRICAL RESISTANCE STRAIN GAGES[1] WHEN COVERED AND NOT COVERED WITH ALUMINUM FOIL

	Warming drift in microinches/inch[2] [3] [4]							
	8 3/4 ma Current		11 4/9 ma Current		13 11/15 ma current		16 2/3 ma Current	
Duration of energizing current, minutes	Gage not covered[5]	Gage covered with foil	Gage not covered[5]	Gage covered with foil	Gage not covered[5]	Gage covered with foil	Gage not covered[5]	Gage covered with foil
½	0	0	0	0	0	0	0	0
1	0	+ 4	+ 2	+ 15	+ 1	+ 19	0	+ 23
2	12	+ 2	— 19	+ 14	30	+ 14	62	+ 9
3	29	— 14	— 51	3	— 73	11	130	37
4	— 44	— 24	— 76	— 26	—113	— 40	—190	— 84
5	— 67	— 38	—106	— 44	—150	— 69	—243	—129
6	— 80	— 52	—135	— 62	—188	— 98	—289	—171
7	91	60	—155	— 84	222	—123	—337	211
8	—101	— 74	—173	—101	—248	—146	—378	—248
9	—112	— 80	—193	—116	—270	—166	—418	—280
10	—124	— 94	—208	—131	—291	—186	—450	—311

[1]Strain gage formed with 0.27 mm grid spacing perpendicular to grain around basswood base using a nitro-cellulose adhesive.
[2]Temperature during testing was 88° ± 1° F.; the relative humidity in the test chamber was 57 ± 1%.
[3]The basswood was at 8% E.M.C.
[3]Constantan wire was suspended in air in the compensating arm of the measuring circuit.
[4]Drift values are the total changes in strain indicated by the gages from the ½ minute measurement to each designated minute of the 10-minute measuring period. Minus sign before strain values indicates shortening of gage length; plus sign indicates an increase of gage length or tensile strain.
[5]Average of three sets of values.

mensions due to loss of moisture in the gage, and the latter would dissipate most of the heat generated in the gage wire.

As for the gages mounted on plexiglass and basswood in the dry atmosphere, a large positive change in dimension was shown, followed by small negative changes. This suggests that positive indicated strains resulted from thermal expansion of substrates and strain gages and that, in the case of plexiglass, the inherent shrinkage of the gage was restrained.

In the case of the gage mounted parallel to the grain on basswood at 50 per cent humidity, only negative change in dimension was recorded during the entire measuring period. This negative change was greater than was evidenced by the unmounted gage at the same relative humidity, and probably resulted mainly from the wood shrinking as it dried.

Gages Mounted on Wood at Three Equilibrium Moisture Contents: Data for this part of the report is summarized in Table 2 and Figs. 5 and 6.

From the drift patterns for the gages after the energizing current was applied, it appears that two phenomena were occurring as is shown in Fig. 5. The phenomenon that predominated during the first few minutes caused the strain gage to register a strain indicating an increase in dimension. This phenomenon was superimposed on another that caused the gage to register a decrease in dimension. The rate of decrease was markedly influenced by the substrate's moisture content, which suggests that this decrease was actually shrinkage of the wood under the gages, shrinkage of the gages themselves, or a combination shrinkage of the wood and gages, as either or both the wood substrate and gages were dried by heat generated in the gage wires. The original increase in dimension suggests that there was an expansion of the wood, the gages, or both resulting from heat generated by the gages; the wetter the wood, the more this expansion was obscured by the shrinkage changes in dimension.

Dimensional changes of the wood substrates can be accounted for by the large amount of heat generated in strain gages and by the poor thermal conductivity of wood and air. Since there were 2 RMS volts across each 120-ohm strain gage, the calculated amount of heat being generated was 1/30th watt or 4.78 calories per minute, which is enough heat, for example, to raise the temperature of one gram of water 4.78°C each minute a gage was energized. Most of this heat would have remained in the wood since its thermal conductivity perpendicular to the grain, although 1/400th that of steel, is still five times that of air. The heat remaining in the wood that was not being conducted away as fast as it was generated was the heat causing the thermal drift shown by the gages.

The long time required for thermal drift of a strain gage, in this instance an SR-4 type A-1 gage, to approach an equilibrium reading can be seen in Fig. 6. After being energized for approximately ten hours, the test gage indicated little change in its rate of decreasing strain. At later periods of time, the specimen began to approach an asymptotic value analogous to an equilibrium strain.

The magnitudes of thermal drifts of individual gages, such as those recorded in Rows A, B, E, F, I, and J of Table 2, could be quite bothersome in strain gage work. Fortunately, as shown in Rows C, G, K and D, H, L of this same table, the drift of a compensating gage can be used to cancel the drift of the active gage. A number of these matched samples show drifts on the strain indicator dial of only a few microinches per inch during their first ten minutes of activation.

Gages Mounted on Wood at Two Angles to the Grain: Drifts of the SR-4 types A-1 and A-7 gages mounted on basswood parallel and perpendicular to the grain are recorded in Table 3. In this series of tests, further evidence that drifts of gages were influenced by physical properties of the substrate is given by the differences in drifts displayed between gages mounted parallel and those mounted perpendicular to the grain.

These differences in drifts, however, can not be attributed entirely to a difference between the thermal expansion and shrinkage properties of wood in these two directions. If the latter were the reasons for the differences in drifts, then gages mounted perpendicular to the grain should have shown about ten times as much thermal expansion as ones mounted parallel, followed by 16 to 33 times as much shrinkage perpendicular to the grain as parallel (1). Yet in these tests, the A-7 gage showed a perpendicular-to parallel-to-the-grain shrinkage ratio of only 1.3 to 1 at the end of 30 minutes of drift.

A correction of this ratio could be made by subtracting from the strain measurements the amount of dimensional change due to thermal expansion of the substrate. This would be quite small, a matter of only a few microinches per inch in the parallel-to-the grain direction, but perpendicular to the grain it would be from 40 to 60 microinches per inch as estimated from the data in Table 3 for the A-7 gage

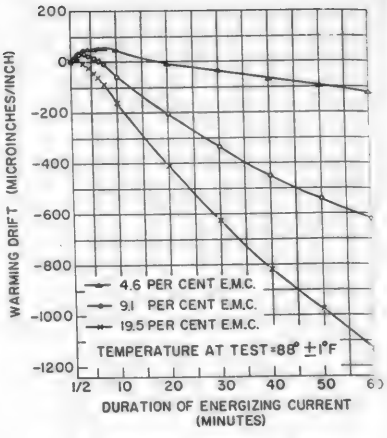


Fig. 5.—Warming drifts of commercial SR-4 type A-1 bonded wire electrical resistance strain gages mounted with nitrocellulose cement on basswood at three equilibrium moisture contents versus duration of energizing current.

mounted perpendicular to the grain on basswood in a dry atmosphere. Even with this correction, the ratio of perpendicular to parallel-to-the-grain shrinkage would still only be 1.4 to 1.

Apparently some factor was either causing excessive drift of the gage mounted parallel to the grain or was restraining the amount of expected drift perpendicular to the grain. The latter factor seems more probable, especially in light of work done by Dove (4). In his article "Strain Measurement Errors in Materials of Low Modulus," he predicts how the stiffness of a strain gage will influence the accuracy of strain measurements. He shows that the accuracy of strain measurements made with a bonded strain gage becomes decreased as the substrate's modulus of elasticity becomes smaller and as the cross-sectional area of the substrate undergoing strain becomes smaller. Furthermore, the decrease in accuracy results from restraint of movement of the test material by the strain gage so that indicated strains are smaller than they should be.

This then gives a possible reason for the lower-than-expected values of strain perpendicular to the grain as compared to those parallel, since the moduli of elasticity of woods such as basswood are 16 to 25 times greater parallel to the grain than they are perpendicular (6).

In further support of the importance of the two different moduli of elasticity causing different-than-expected drifts is the probability that only small cross-sectional areas under the gages were undergoing thermal expansion and shrinkage from heat in the gages. Actually, the stiffness of the gages apparently prevents thermal drifts from becoming much greater than they are.

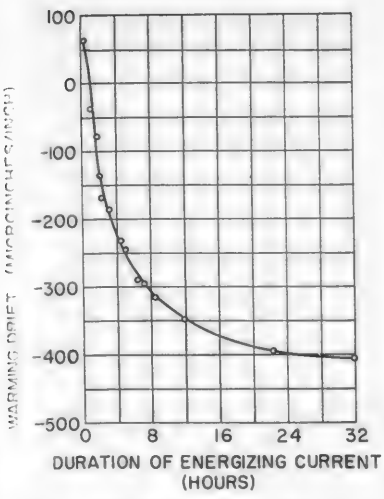


Fig. 6.—Warming drift for 32 hours of SR-4 type A-1 strain gage mounted perpendicular to the grain with nitro-cellulose cement on basswood at 4.6 per cent e.m.c.

The greater drifts of the A-7 gages than of the A-1 gages resulted from closer spacing of grid wires in A-7 gages causing a higher heat concentration in these gages. Heat concentrations and thus rates of drifts should be approximately inversely proportional to the areas of the grids of gages. Since the grid area of an SR-4 type A-1 gage is 0.114 square inch and that of an SR-4 type A-7 gage is 0.027 square inch, their rates of drifts would be expected to be in the ratio of one to four, although data for this experiment showed greater differences.

Gages Covered and Not Covered with Aluminum Foil at Four Current Levels: Drift strains indicated by a bond resistance strain gage for ten-minute periods at four energizing current levels are given in Table 4. The table also shows the data for the gage covered with aluminum foil.

From the table it can be seen that the higher the energizing current, the greater the rate of drift. When the gage was not covered with foil, drifts of the gage at the four current values showed the following relative magnitudes at the end of ten-minute measuring periods: 3.6: 2.3: 1.7: 1.0. Currents in the gage taken in the same order were in the ratio of 1.90: 1.57: 1.31: 1.00, and squares of the currents were in the ratio of 3.5: 2.5: 1.7: 1.0. Since heat is a function of the current squared, an analogy can be drawn between the amount of heat generated in the gage and its thermal drift.

By adding the foil wrap to the gage, approximately one-third reduction in drift occurred at the end of the ten-minute measuring period. No doubt this resulted from the foil wrap conducting heat away from the gage surface.

Summary and Conclusions

When most commercial types of bonded electrical resistance strain gages are used on dielectric materials, undesirable drifts of the gages occur as they are energized in the measuring circuit. On a non-hygroscopic material such as plexiglass, a drift over a ten-minute period is predominantly one indicating an increase in dimension of the substrate by the strain gage. This drift is attributable to the thermal expansion of either the gage or the gage and the substrate. It is explainable on the basis that heat accumulates in the vicinity of the gage because of poor heat dissipation characteristics of the substrate.

In addition, drifts of bonded electrical resistance strain gages on a hygroscopic dielectric such as wood are affected simultaneously by shrinkage of the wood under the gages as the wood is dried by heat generated in the gages. Gages with narrow grid-wire spacing when mounted perpendicular to the grain of wood show drifts that are positive, which indicates thermal expansion at the beginning of the time that the energizing current is applied. The positive drift is followed by negative drift, which indicates shrinkage of the wood. The negative drift changes its rate of increase in strain only slightly after the energizing current has been on for one hour. If the energizing current is left on for a sufficient length of time, however, an asymptotic drift strain will be approached. The higher the moisture content of the wood, the greater is the rate of negative drift, which may almost completely obscure positive drift. When the same types of gages are mounted parallel to the grain, positive drift is not as apparent as for the mounting in the perpendicular direction, nor is the total negative drift as large if the energizing current is left turned on for a long period of time. The smaller thermal expansion and shrinkage properties of wood parallel to the grain account for the difference.

Warming drifts of strain gages on wood vary with operating conditions and different types of gage construction. With strain gages that have narrow wire spacing, which permits heat concentration in the gages, the drifts increase directly in proportion to the square of the current used to energize the gages. Gages made with the widest grid-wire spacing will have the smallest drifts on wood because the heat concentration in these will be least. Methods of dissipating heat in gages, such as covering them with foil, will also reduce their drifts.

For measuring purposes, the effect of the warming drift of a bonded electrical resistance strain gage on wood can be reduced by placing the same type gage in the compensating arm of the measuring circuit. This gage should be mounted on a sample of wood carefully matched with that of the active gage as to species, moisture content, angle of mounting to grain, and physical properties. Since the warming drift for a gage changes its rate and direction with the amount of time the energizing current has been applied, active and compensating gages should be energized at the same time. It is also possible that a compensating gage will have a drier substrate and consequently a different drift pattern after it has been used with several active gages. Therefore, the safest policy would be to use a separate compensating gage with every active gage.

Desirable techniques for the use of bonded electrical resistance strain gages on wood are the following:

1. Gages should be constructed to cause as little heat concentration as possible when the energizing current is passed through them. This may be achieved by making the gage from only one or two strands of strain-sensitive wire or by having a comparatively wide spacing between adjacent strands of the strain-sensitive wire. The dissipation of heat may be improved by placing a heat-conductive material in contact with the gage.

2. A compensating gage should be used in the Wheatstone bridge circuit.

   a. The compensating gage should be the same type as the active gage.

   b. The compensating gage should be mounted on a wood sample matched with that of the active gage as to species, moisture content, and specific gravity.

   c. The test specimens carrying both the active and compensating gages should be kept at the same conditions of temperature and relative humidity.

   d. A separate compensating gage should be used for each active gage, and this compensating gage should only be energized when the active gage is energized.

3. Low energizing currents should be used so that the magnitudes and rates of warming drifts of the strain gages will be at a minimum.

4. Wood with a low moisture content should be used in testing in order to obtain the maximum stability and least variation between drifts of active and compensating gages. The lower the e.m.c. of wood substrates, the less warming drift there will be from shrinkage of the wood substrate.

Data authenticating the accuracy of bonded electrical resistance strain gages on wood is still scarce. More work must be done to improve the performance of these sensitive strain-measuring devices for use on wood after the factors affecting their accuracy are recognized.

Literature Cited

1. Anon. 1955. Wood Handbook. Agr. handbook 72. USDA. Forest Prod. Lab. Madison, Wis.
2. Clark, L. N. 1954. Strain gauge bridge for creep tests. Jour. Sci. Instruments. XXXI (8): 300–301.
3. Dietz, A. G. H. 1949. Short-time creep tests on Douglas-fir. Proc. FPRS. III: 352–360.
4. Dove, R. C. 1955. Strain measurement errors in materials of low modulus. Proc. Amer. Soc. Civil Eng. LXXI (1): 1–10.
5. Grossman, P. V. A., and R. S. T. Kingston. 1954. T. P. 16–2; Creep in tension and compression, progress report No. 1; the influence of stress on creep. Div. of Forest Products, CSIRO, Melbourne, Australia.
6. Hearmon, R. F. S. 1948. Elasticity of wood and plywood. Forest Products Research Special Report No. 7. Dept. of Scientific and Industrial Research, London, England.
7. Noren, B. 1952. Mät 'n ing au töjning och Krypning i trö (The Measurement of strain and creep in wood: Bulletin No. 29 B). Medd. suenska Träforskn Inst., Stockholm, Sweden.
8. Scott, I. S., and R. S. T. Kingston. 1948. The manufacture of electrical resistance strain gauges for use with timber. Progress report No. 1. Div. of Forest Products, CSIRO, Melbourne, Australia.
9. Scott, I. S., and R. S. T. Kingston. 1949. A method of calibrating electrical resistance strain gauges. Progress report No. 2. Div. of Forest Products, CSIRO, Melbourne, Australia.
10. Solvey, J., and G. L. Belcher. 1952. Applications of electric resistance strain gauges to strain measurement in plywood faces of sandwich panels: Structures and materials note 198. Dept. of Supply, Aero, Res. Lab., Melbourne, Australia.
11. Youngquist, W. G. 1957. Performance of bonded wire strain gages on wood. USDA, Forest Prod. Lab. Report No. 2087. Madison, Wis.

VOLUMETRIC METHOD OF DETERMINING

Dry Weight of Green Aspen Bolts[1]

JOHN HAYGREEN

Graduate Assistant, Department of Forest Products, Michigan State University, East Lansing

Estimates of dry weight from green weight appear to be impractical for an accurate estimate. With conversion factors presented here, however, dry weight can be found accurately by volumetric displacement measurements.

Fig. 1.—Measuring the volume of aspen bolts by displacement.

MOST PURCHASES OF BOLTWOOD today are based upon either cord measure or green weight. Neither of these methods, as commonly practiced, is reliable for providing consistent information as to the actual weight or volume of dry wood substance present. A type of measurement that could supply accurate information would not only make it possible to set purchase prices more realistically, but would be helpful to industry and researchers in the determination of product yield standards. The technique of obtaining the volume of bolts by water displacement has considerable promise of being such a method of measurement.

The possible wide variation in the amount of wood substance contained in a unit cord of 128 cubic feet is well known. Cord measurement gives only approximate information about the volume of green wood in the unit, and even less information about the volume or weight of dry wood present.

[1] 1958 Wood Award entry.

The Author: John Haygreen graduated from Iowa State College in general forestry. He earned his MS degree at Michigan State, and is currently working toward his PhD.

The measurement of boltwood by weight also poses several problems. The principal problem is that the bolts may lose moisture, and thus weight, quite rapidly after being cut. An estimate of the dry weight based upon the established relationship between the weight of green boltwood and the corresponding dry weight, becomes progressively greater in error as it is applied to boltwood in progressive stages of drying.

Since the relationship between the actual weight and the dry weight of boltwood is subject to continual change after the wood is cut, any estimate of the dry weight made on the basis of green weight is subject to considerable error unless moisture tests are made. Tests to determine the average moisture content would be necessary even if boltwood is weighed immediately after it is cut since with a species such as aspen the moisture content may vary during the year. Jensen and Davis (7)[2] found that the average moisture content of quaking aspen in their samples varied from 80 per cent in the summer to 113 per cent in the winter. This could mean a difference during the year of approximately 15 per cent in the green weight of a unit of dry wood.

The limitations of weight determination and of cord measure could quite possibly be overcome by the water displacement technique. This method would involve submerging loads of boltwood in a water tank and obtaining the volume of wood, or of wood plus bark for unpeeled bolts, by the change in the water level. It is possible to convert the volume obtained from displacement into the corresponding dry weight if the relationships (conversion factors) between the volume of green bolts and the amount of dry wood are established.

The average volumetric shrinkage of bigtooth aspen from a green to a dry condition is listed in the literature as 11.8 per cent. Thus, if a given amount of green aspen boltwood is air-dried to 20 per cent moisture content, the volume would decrease by only about 4 per cent, whereas the weight could decrease as much as 40 per cent. It is thus evident that the amount of dry wood present in a given amount of green wood could be much more accurately estimated throughout progressive stages of air-drying by use of a conversion factor based upon green volume than by use of a factor based upon green weight.

[2] Numbers in parentheses refer to the Literature Cited.

Purposes of the Study

The primary purpose was to establish factors for converting the green volume of peeled and unpeeled aspen bolts into estimates of the dry (oven-dry) weight of wood substance present. An indication of the influence that the diameter of bolt and its location in the tree might have upon a conversion factor was also desired.

The second purpose of the study was to compute a factor for converting green weight of aspen into dry weight, and to compare its accuracy as affected by changes in moisture content with the one computed for converting green volume to dry weight. To make such a comparison, the extent and rate of weight and volume losses that occur when aspen boltwood is stacked in an exposed location were determined.

Fig. 2.—Author lowers a bolt in the tank, which extends about 5 feet below the ground.

Description of Sample

All data in this study were obtained from samples of bigtooth aspen (*Populus grandidentata* Michx.) taken in central Michigan. The four-foot bolts used in the study of losses in moisture content, weight, and volume during air-drying were obtained from two areas. The first sample (sample A), consisting of 63 bolts, was cut on the Manistee National Forest. A 10-inch test section, used in the study of physical properties, was cut from the stem below each bolt removed for the drying sample.

The second sample (sample B), consisting of 60 bolts, was cut on the Allegan State Forest near Allegan, Michigan. No 10-inch test sections were cut from this area. These bolts were cut in the woods into eight-foot lengths, and when delivered to the drying area were cut into the desired four-foot lengths. One member of each such pair was peeled and the other was left unpeeled to obtain matched specimens for a direct comparison between peeled and unpeeled bolts during air-drying.

A total of 29 trees were cut to obtain the 63 bolts in sample A. The average height of these trees was 54 feet, and the average diameter inside bark at one foot above ground was 7.3 inches. The site index was estimated at 68 (8). Ninety per cent of the trees cut were in the 35 to 42 year age class. The average age was 38 years.

The bolts in sample A, and the corresponding 10-inch test sections, were selected to include bolt diameter classes from three to nine inches and bolt height classes from one foot to 33 feet. Fig. 3 illustrates the distribution of the sample.

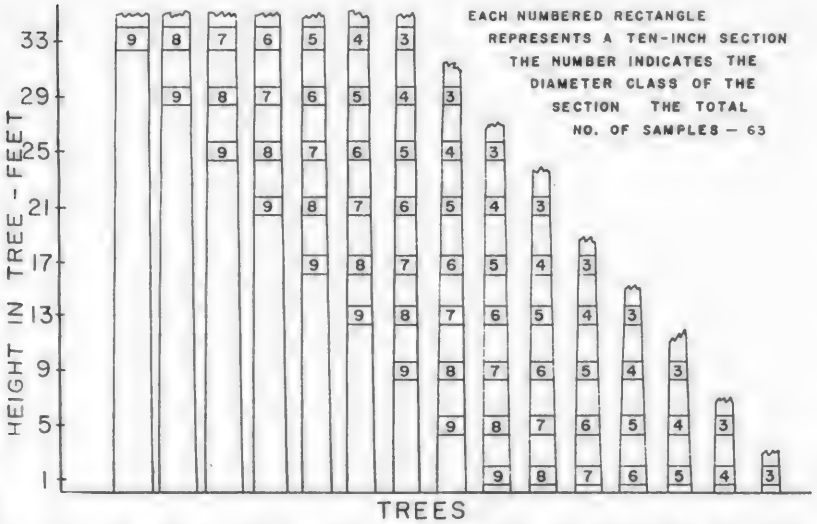


Fig. 3.—Pictorial representation of sample A. Diameter class and height of each test section is indicated. The number of trees cut was greater than indicated.

In the selection of sample B, no stratification was made involving height in the tree. Six diameter classes were recognized, ranging from three inches to eight inches diameter inside bark. Five eight-foot bolts were obtained in each diameter class. The average age of trees in sample B was 33 years. The average height of the 11 trees cut to obtain the sample was 47 feet. The site index for this sample was estimated as 65, just slightly less than for sample A.

Table 1.—PHYSICAL PROPERTIES OF BIGTOOTH ASPEN IN SAMPLE A, AVERAGED BY DIAMETER CLASSES

Physical properties	Bolt diameter classes							Grand mean
	3 In.	4 In.	5 In.	6 In.	7 In.	8 In.	9 In.	
M.C.[1] green wood	83.6	87.4	101.2	92.3	104.1	94.2	94.7	93.9
M.C. green bark	70.4	69.3	75.5	70.9	70.7	72.1	74.6	71.0
M.C. wood plus bark	80.9	83.6	96.2	88.3	97.2	90.3	91.0	89.6
Sp. gr. wood—dry vol. basis	0.40	0.39	0.40	0.42	0.43	0.44	0.45	0.42
Sp. gr. wood—green vol. basis	0.36	0.36	0.37	0.38	0.39	0.40	0.40	0.38
Sp. gr. bark—green vol. basis	0.61	0.60	0.59	0.62	0.60	0.59	0.58	0.60
Vol shrinkage of wood[2]	10.0	8.2	9.0	10.0	9.9	10.2	10.4	9.7
Vol shrinkage of bark[2]	25.2	25.1	27.2	25.0	24.7	26.1	26.8	25.7
Per cent of bark vol.[3]	14.1	13.7	12.7	12.3	14.1	13.0	13.6	13.4
Per cent of heartwood	10	9	9	14	17	17	18	13

[1]Moisture content.
[2]Expressed as a per cent of the green volume.
[3]Expressed as a per cent of the volume of wood plus bark.

Experimental Procedure

Weight and volume measurements were taken on both samples A and B every two weeks. The four-foot bolts were stacked in a rack constructed to afford optimum drying conditions. A rough board roof, supported several feet above the pile, kept off direct precipitation. The drying rack was built six inches above the ground to allow air to circulate beneath the pile.

The bolts were weighed separately, and the weights were recorded by bolt number. The volume of the bolts was determined by immersion in a tank. A sight glass was fitted to the side of the tank, and a steel tape was fastened to the glass. The volume equivalent to one inch of displacement in this tank was 0.066 cubic foot. Sample A was under study during the summer and fall of 1956, and sample B during the summer of 1957.

In the laboratory, a one-inch cross-sectional disk was cut from each 10-inch test section. These were used to determine the data on physical properties of aspen listed in Table 1. A two-way analysis of variance was computed for each of the properties, with diameter of bolts and height in the tree as the independent variables.

The determination of average conversion factors and of the variation of these factors were two of the primary objectives of this study. The significance of differences in the conversion factors between diameter and height classes was established by means of analysis of variance. These conversion factors, however, were computed from a number of variables: specific gravity, per cent of bark, and per cent shrinkage of wood. The extent of change of these variables will be considered first, so that the variations found in the conversion factors may be better understood.

Variation of Physical Properties

Possible variation of the specific gravity of aspen grown in various stands and sites was thought to be of particular importance. Changes in specific gravity from stand to stand would cause corresponding changes in the factor needed to convert green volume to dry weight. To obtain some indication whether such variations exist, specific gravity was studied in somewhat greater detail than the other physical properties mentioned. In addition to the independent variables diameter and height as used in the analysis of variance, a third variable—rate of growth—is known to have an important relation to the specific gravity (10). The results of a multiple correlation (11) on the basis of these four variables follow:

Specific gravity of wood Y	Diam. of bolts X_1	Rings per inch X_2	Ht. above ground X_3
Correlations of Y with X's	+0.471	—0.399	—0.144
Standard regressions of Y on X's	+0.185	—0.331	—0.257

$$Y = 0.465 + 0.004X_1 - 0.004X_2 - 0.001X_3$$

Specific gravity was found to vary significantly between bolt diameter classes, but not between height classes. Fig. 2 illustrates the increase of specific gravity with diameter. The correlation coefficient of bolt diameter and specific gravity was found to be slightly higher and opposite in sign than the correlation coefficient of rings per inch and specific gravity. The correlation indicated that the specific gravity increased with an increase in diameter, but decreased with an increase in the number of rings per inch. The standard error of the estimate for the multiple regression was found to be 0.036. This indicates that the regression formula does an adequate job of estimating the specific gravity. The multiple correlation coefficient of 0.506 was significant at the one per cent level.

The average volumetric shrinkage of wood based upon green volume was found to be 9.7 per cent. This figure did not vary significantly with either bolt diameter or height classes.

The per cent of bark volume is the third important variable used in computing some of the conversion factors. The analysis of variance indicated that this percentage varied significantly with the height in the tree, but not with the diameter of the bolts.

The average moisture content of green wood and of green bark was also established, and was used in computing a factor used to convert green weight to dry weight. An analysis of variance indicated no significant differences in the moisture content of the wood between the bolt diameter or the height classes.

Table 2.—DEFINITIONS AND VALUES OF CONVERSION FACTORS FOR BIGTOOTH ASPEN BOLTWOOD

Conversion factors[1]	Values computed from the total wts. and vols. of test disks	Values computed from the calculated sp. gr., per cent of bark, shrinkage, and m.c.	
		Sample average	95% confidence interval
CF-1	21.06	20.46	20.04–20.88
CF-2	24.30	23.61	23.07–24.16
CF-3	0.781	0.782	0.776–0.789
CF-4	0.901	0.903	0.899–0.907
CF-5	0.422	0.425	0.417–0.433
CF-6	0.507	Not computed	

[1]CF-1—Factor by which to multiply the vol. of unpeeled bolts, in cu. ft., to estimate the dry weight of wood, in pounds.
CF-2—Factor by which to multiply the vol. of peeled bolts, in cu. ft., to estimate the dry weight of wood, in pounds.
CF-3—Factor by which to multiply the vol. of unpeeled bolts to estimate the dry vol. of wood.
CF-4—Factor by which to multiply the vol. of peeled bolts to estimate the dry vol. of wood.
CF-5—Factor by which to multiply the green weight of unpeeled bolts to estimate the dry weight of wood.
CF-6—Factor by which to multiply the green weight of peeled bolts to estimate the dry weight of wood.

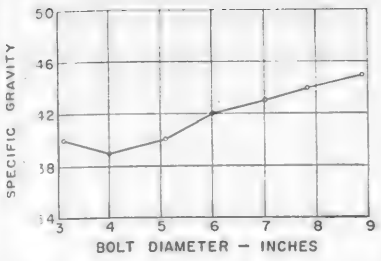


Fig. 4.—Relation of specific gravity of wood on dry volume basis to bolt diameter inside bark.

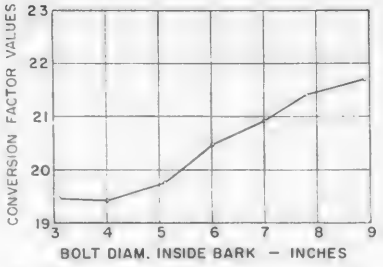


Fig. 5.—Variation of conversion factor number one with bolt diameter.

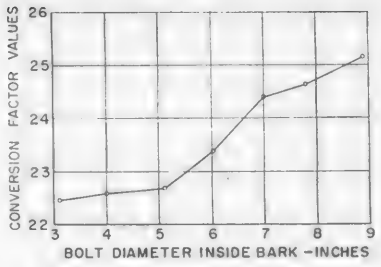


Fig. 6.—Variation of conversion factor number two with bolt diameter.

Conversion Factors

Conversion factors, that is, the relationships between green weight or volume and dry weight or volume, were computed in two ways. The first method used was a technique that would be relatively easy for anyone to follow who wished to establish a conversion factor for another species. The reasons for variations cannot be analyzed, however. The total green and dry weights and the total green and dry volumes of the test sections were used to establish the desired conversion factors.

For example, the factor used to convert green volume in cubic feet to dry weight in pounds was found by dividing the total number of pounds of dry wood in the one-inch-thick test disks by the number of cubic feet of green wood and bark in these disks. See Table 2 for a list of factors computed in this study.

By means of this first method of calculation, the conversion factor to change the green volume of wood plus bark to the dry weight of wood was found to be 21.06. Thus a load of unpeeled boltwood with a volume of 1000 cubic feet, as determined by immersion, contains an estimated 21,060 pounds of dry wood substance.

The second method of computing the factors made use of the moisture content, specific gravity, shrinkage coefficient, and percentage of bark by volume, as determined from the test sections. The emphasis in this study was on this method of computation because it was thus possible to better analyze the various elements that make up the conversion factors. All tables and graphs in this paper refer to factors determined in this way.

Three types of conversion factors were computed: 1) to convert green volume to dry weight, 2) to convert green volume to dry volume, 3) to convert green weight to dry weight. The above were computed for both peeled and unpeeled boltwood. Figs. 5 and 6 illustrate the variation of these relationships with bolt diameter classes in the cases where a statistically significant difference was indicated.

There is a 3 per cent difference between the two methods of calculation for the first two conversion factors. The differences are believed to have occurred as a result of errors in the measurement of the dry volume of the test disks. These measurements were used only in computing the factors by the second method.

The first kind of relationship investigated was that between green volume and dry weight. The analysis of variance indicated that factors one and two differed significantly between diameter classes, but not between height classes. This finding parallels the variation of specific gravity.

No significant differences in the means of factors three, four or five were indicated between bolt diameter or height classes. The hypothesis that the means are equal throughout these classes was thus accepted.

Drying Losses of Aspen Boltwood

The per cent of weight and volume losses for samples A and B are illustrated in Figs. 7 and 8. The unpeeled bolts in samples A and B lost an average of 0.6 per cent in volume and 4.7 per cent in weight during the first two weeks of drying. After six weeks, these losses had increased to 12 per cent of the original weight and 1.5 per cent of the original volume. The differences in the drying rates between the unpeeled bolts in samples A and B can be attributed to the weather differences during the summers of 1956 and 1957, and also to the difference in the dates on which the samples were cut.

The loss in weight of the peeled bolts was considerably greater, for a given period of time, than that for the unpeeled bolts. In sample B, the peeled bolts lost almost four times as much weight as the unpeeled during the first two weeks of drying. After six weeks, the peeled-bolt weight loss was only twice that of the unpeeled.

Volume loss in the peeled bolts was more rapid than in the unpeeled, but not to the extent of the weight losses. During the first six weeks, volume losses were found to be about 1.5 times as great for the peeled wood as for the unpeeled. It should be noted that, after one month of drying, the peeled stock had lost only about 2 per cent of the original volume.

Application of Conversion Factors

All data used in the calculation of conversion factors were obtained from one site and from one age group. Further study is necessary to determine whether the conversion factors established in this study hold for other age groups and other sites.

The volume measurements obtained by displacement can be converted to either volume or weight at any desired moisture content as dictated by the moisture content of the final product. In most cases, dry weight will give more information about yield of the final product than will the volume, but in some cases the yield of boltwood expressed as volume may be desired.

The ratio of dry volume to green volume remained constant throughout the height and bolt diameter classes. This means that an organization purchasing aspen boltwood on a *dry volume basis,* as established by displacement, could expect to receive the same dry volume per dollar regardless of whether the bolts purchased averaged four inches or nine inches in diameter.

The weight of dry wood in a cubic foot of green bigtooth aspen was found to increase with an increase in bolt diameter and also with an increase in the growth rate. Therefore, a company purchasing aspen on a *dry weight basis,* as computed by means of the average conversion factor, could expect to receive more dry wood per

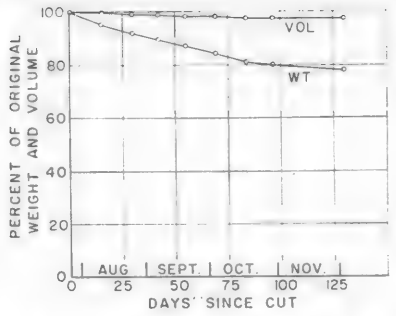


Fig. 7.—Volume and weight losses of aspen boltwood from sample A.

dollar when buying larger diameter or more rapidly grown material.

A more nearly constant unit cost could be maintained if the conversion factor corresponding to the average diameter of bolts in the shipment was used to compute the dry weight. The variation of dry weight with diameter could be expected to be similar on other sites, though the average conversion factor would be subject to change from that presented in this report.

When comparing weight and water displacement as ways to estimate the amount of dry wood in boltwood, the change in these values due to drying prior to measurement is an important consideration. As an illustration, assume that a unit of unpeeled boltwood when freshly cut would sell for $1600 on the basis of dry weight, as determined by both displacement and green weight. After six weeks of drying under conditions as described for sample A, this unit would bring $1581 if measured by displacement, and only $1436 if sold by weight. After 18 weeks it would bring $1566 if sold by displaced-volume and only $1256 if sold by weight.

If peeled bolts were used in the preceding example in place of unpeeled bolts, the price based on displaced-volume after six weeks would be $1556 rather than $1581. Both of these changes in price can be considered slight when compared to those of the price as set by weight measure.

When wood is bought by weight, the unit cost of dry wood substance would be subject to considerable variation with changes in the length of time from cutting until weighing. It is to the buyer's advantage to buy wood that is partially dried unless the buyer prefers green wood because of the nature of the manufacturing process. Jeffords (6) pointed out that, where green wood is preferred, buying by weight has the advantage of encouraging producers to haul when the wood is still green.

Two points are of primary importance when comparing the accuracy of displacement and green-weight methods as means of establishing the dry wood content of aspen boltwood. The first is that changes in the estimate due to drying losses are much greater for the green-weight system. A maximum change during one month for the displacement method would be about 2 per cent, while the weight method was found to change 30 per cent. The second point is that the estimate of dry wood content made from the green weight will change with variations in the moisture content of the green bolts. This moisture content has been found to vary up to 30 per cent between different seasons of the year. Moisture content has no effect upon the estimate made from the volume of displaced water.

The design of a displacement tank for use by industrial or research organizations is beyond the scope of this paper; however, any vertical-walled tank with an attached sight gauge should suffice. In a 10-foot-square tank, a one-inch displacement of water would indicate 8.3 cubic feet of boltwood. Loading and unloading of the displacement tank could be performed by cranes or power hoists already available at most installations.

Conclusion

The water displacement technique can be used to determine the dry content of green boltwood in terms of weight or volume. By use of this technique, therefore, purchases can be based not upon an arbitrary quantity, but upon the amount of wood that will actually be used in the manufacturing process. Information pertaining to the actual amount of wood substance being used in a process would prove helpful in research on yields from various processes, and to industry when standards are established as methods of control.

Despite the obvious mechanical difficulties of measuring boltwood by displacement, this method should prove helpful when more accurate information about the raw material is desired than can be obtained by cord or weight measurements.

The ratio of dry volume to green volume remained constant for both peeled and unpeeled aspen bolts despite changes in both bolt diameter and the height in the trees from which the bolts were cut.

The ratio of dry weight to green volume increases with an increase in the specific gravity of the wood. On the site studied, specific gravity of wood increased with increases in diameter and in growth rate. Average conversion factors were computed for

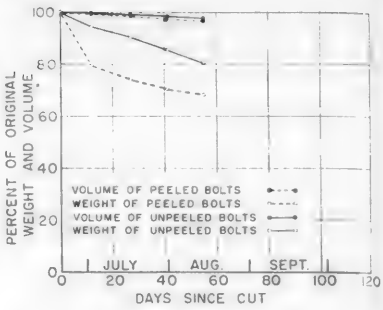


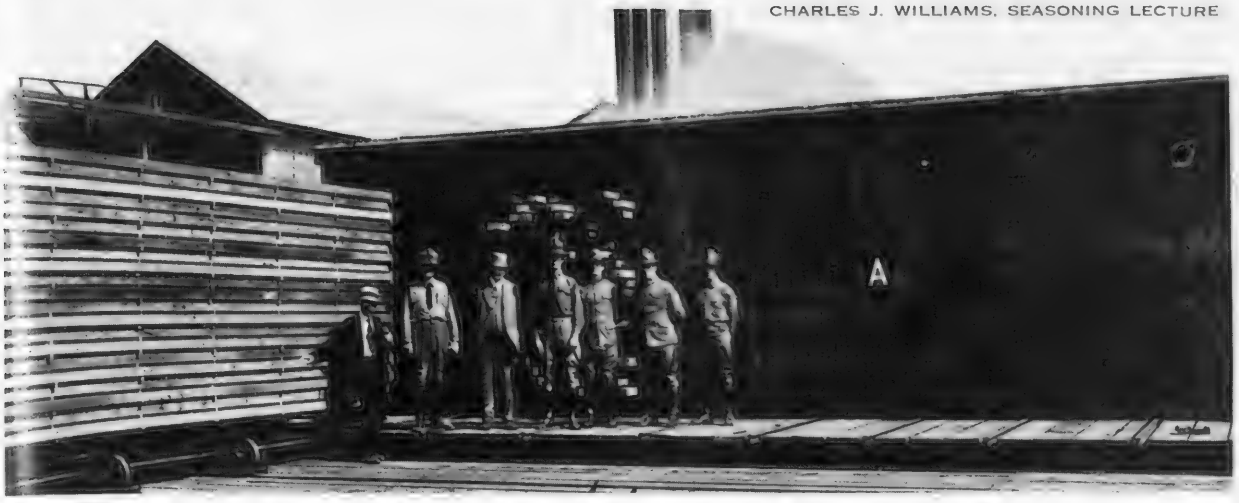
Fig. 8.—Weight and volume losses observed in both peeled and unpeeled aspen bolts under good air-drying conditions. Data are from sample B.

each bolt diameter class. These can be used to give a more accurate estimate of the dry weight than would be obtained by the use of just one factor for all diameters.

Green-weight measurements can also be used to estimate dry weight by the use of conversion factors. Such a system is impractical when an accurate estimate is desired because of the wide variation of the moisture content during the year, and also due to the rapid change in the true conversion factor when the bolts are subjected to drying.

Literature Cited

1. Brown, H. P., A. J. Panshin, and C. C. Forsaith. 1952. Textbook of Wood Technology. Vol. II, New York: McGraw–Hill.
2. Chapman, H., and D. B. Demerit. 1936. Elements of Forest Mensuration. Albany: Williams Press.
3. Goulden, C. H. 1952. Methods of Statistical Analysis. New York: John Wiley and Sons.
4. Hale, J. D. 1955. Thickness and density of bark for six pulpwood species. Pulp and Paper Mag. of Canada, Dec. 1957.
5. James, L. M. 1957. Marketing pulpwood in Michigan. Ag. Exp. Sta. Michigan State U., Special Bul. 411.
6. Jeffords, A. I., Jr. 1956. Trends in fine pulpwood marketing in the South, J. For., Sept.
7. Jensen, R. A., and J. R. Davis. 1953. Seasonal moisture variations in aspen. Minn. Forestry Notes, No. 19, U. of Minn., St. Paul.
8. Kittredge, J., Jr., and S. R. Gevorkiantz. 1929. Forest possibilities of aspen in the Lake States. Minn. Ag. Exp. Sta., Tech. Bul. 60.
9. Olson, H. S. 1953. The purchase of wood by weight, Proc. Upper Miss. Valley Section, FPRS.
10. Paul, B. H. 1956. Specific gravity of Populus species and hybrids. U. S. Forest Prod. Lab. Report 2060.
11. Snedecor, G. W. 1946. Statistical Methods. Ames: Iowa State College Press
12. Taras, M. A. 1956. Buying pulpwood by weight. Southeast Forest Expt. Sta., Asheville, Station Paper No. 74.
13. Yandle, D. O. 1956. Statistical evaluation of the effect of age on specific gravity in loblolly pine. U. S. Forest Prod. Lab., Report 2049.



Mr. Tiemann (left) with the first load of seasoned lumber from a Signal Corps kiln during World War I.

HIGHLIGHTS LEADING UP TO

Modern Kiln Drying[1 2 3]

HARRY D. TIEMANN
Kiln Drying Specialist (retired)
Madison, Wis.

Even in 735 BC, men wrote of "timber drying by the ancients". Highlighted here, the science of kiln drying has two basic aspects—understanding the behavior of wood, and operating and controlling the kiln itself.

KILN DRYING SAWN LUMBER is called for mainly where its use is to be in dry or in cold climates, where buildings are artificially heated and for preservative treatment, for reducing shipping weight, and for preventing damage apt to occur in air drying such as sap stain, checking, warping, and so forth.

Injuries that commonly occur in air drying can often be prevented or greatly reduced by properly kiln drying the green wood directly from the saw. But there is little that can be done to remedy damage already produced by natural seasoning. If the lumber is undamaged, kiln drying of material already air-dried below its fiber saturation point clear through is a comparatively simple matter. At a national conference in 1924 losses from poor seasoning were given as the greatest single item of waste involved in converting the standing tree into the product for ultimate use. In 1956 a survey by the Southeastern Forest Experiment Station estimated the loss from air seasoning green pine as a total loss in monetary value of over 13 per cent.

That too little attention in this country has been paid to quality rather than quantity is now being realized by the lumber industry. An editorial in the Southern Lumberman of April 1, 1958 reported that, at the annual meeting of the Western Pine Association, S. V. Fullaway stated, "The two basic factors in the loss of lumber markets are poor quality and failing to meet changing market requirements. Too much of the lumber produced in this country is of poor quality." This fact was emphasized by the Western Forest Industries Association by the statement that "The lumber industry must produce a better product if it wants to share in the home building market." The editorial ends by stating that "Quality is the keystone of any successful trade promotion. There is no substitute for quality."

By present technical methods with improved kilns in drying fresh green timber such as gunstocks, airplane parts, wagon material, and so forth, loss was reduced to less than 1 per cent during the war. This is possible today for lumber by careful kiln drying. Since injury is most serious in upper grades, which come mainly from the older trees, this means a saving of our virgin forests.

Prejudice Against Kiln Drying

Years ago, there was a strong prejudice in England and other European countries against kiln-dried timber. This was due to bad results, lack of knowledge, and improper methods and equipment.

In most European countries very careful air drying was universal practice. Logs were usually slash sawn, and the boards were stacked for drying—often each log separately, and in the order in which sawn. Artificial drying was considered unnecessary or rarely used except after air drying.

The use of heat to dry wood has, of course, been practiced from time immemorial, but a scientific knowledge of the subject and its technical application seem to be of comparatively recent development.

[1] Sponsored by the Moore Dry Kiln Co. in cooperation with the FPRS Wood Drying Division.

[2] Presented at the Keynote Session, FPRS 12th National Meeting, June 22–27, 1958, in Madison, Wis.

[3] A complete copy of this report, including 59 literature citations is available on request from the FPRS National Office.

Harry Tiemann (right) receiving his honorarium from Pat Williams Jr. of Moore Dry Kiln Co. Tiemann received his MS in mechanical engineering from Stevens Institute in 1897, and spent 35 highly productive years at the US FPL in timber physics as well as in kiln drying.

These water-spray kilns installed at Rock Island Arsenal in 1918 are perhaps Tiemann's most famous.

Lafayette "Dry Kiln" Moore in one of his "moist air" kilns of the late 1890's—early 1900's.

Artificial Drying Nearly 3,000 Years Ago!

The subjecting of green lumber to the fumes from burning slash as fuel in inclosed rooms was a very ancient practice. Hesiod in 735 B. C. said, "As the homes of the ancients were so smoky it must easily be comprehended how by means of smoke they could dry and harden pieces of timber."

Virgil seems to have been aware also of the use of this method, about 35 B. C.: "Of beech the plough-tail, and the bending yoke of softer linden hardened in the smoke." And furthermore: "These long suspend where smoke their strength explores and seasons into use and binds their pores."

Such methods were used in France over a hundred years ago. Seasoning by smoke is practiced even today in remote locations. Loft drying and stacking in heated rooms, also, has been used from time immemorial, and still is in many countries.

Preliminary soaking before drying to leach out sap and improve the quality has long been practiced in Japan and in Sweden. Extensive scientific experiments on the effect of preliminary soaking were made in Germany by Gabriel Janka about 1904. Results are unimportant, although long soaking (many years) especially in salt water does reduce shrinkage slightly and improve drying conditions an appreciable amount. (See "Kiln Drying Lumber," pages 25–28, tables).

Early Developments and Patents in Europe and U.S.A.

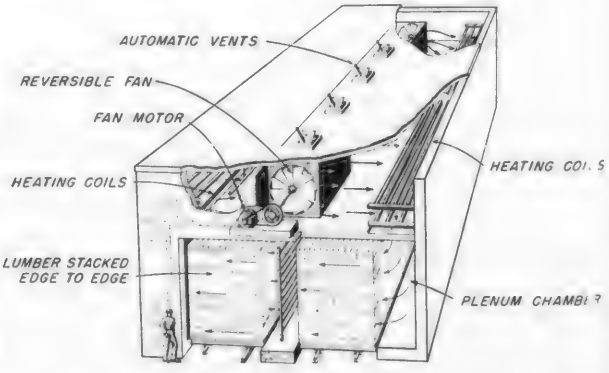
In England, the "Cumberland Method" was patented in 1720 by John Cumberland. This is described as "a process of heating, drying, seasoning, and bending timber, wood plank, or board," and consisted of placing the planks in wet sand and "heating until the desired condition of suppleness is attained and then heating until the juices are extracted." It was used for a long time for timbers in building ships. Over a hundred years later, in 1825, a "process to prevent shrinking and increase durability" was patented by Atlee. This is apparently identical to the recent Forest Products Laboratory "Staypack" by Stamm.

In 1844, David and Symington patented a process of "drying, seasoning and hardening wood", which called for heated air impelled at a rate of 100 feet per second (probably in the duct) that started at a temperature of 150° to 200° F. for green wood and gradually rose to 400° or 500° F. It is stated that "the heat kills the seeds of dry rot." An early recorded invention is that of Langton in 1825 for a process of removing the sap by steaming followed by a vacuum, in a hot-jacketed cylinder.

It is worth noting that a natural draught "stove" much like the recent Grand Rapids kiln, with vertical chimneys so arranged as to suck the cooled damp air up from the bottom, was patented in England by Thomas Holmes in 1853. Also the same year an "oven" for drying and impregnating beech wood for carpenters' planes was patented by Slater and Tall. The beech was first steamed several hours, then subjected to a vacuum and oil admitted to fill the pores, then dried in a current of air produced by a blower. Some four other driers for wood were patented in England up to 1865.

English patents are not classified according to the material being dried, such as timber, and there are many thousands of them for drying "apparatus" dating back to 1636. It is not a simple matter, therefore, to determine what apparatus is suitable for drying timber.

Lumber from the mill traveled along this tram to be edge-stacked for drying in these old smoke kilns.



Cut-away of a modern, internal-fan compartment kiln.

This battery at Kirby Lumber Corp. typifies the change from resistance to acceptance of dry kilns in modern lumber production.

Not much attention was given in England to artificial drying until recently. However, the Sturtevant Co. blower kiln has been used for over half a century, and a progressive natural draught kiln by the Erith Engineering Co. for a longer time.

It should be observed that "lumber" as used in England is a spurious word and that *timber* is the orthodox term, as used in England and elsewhere. Thus "Timber Drying" is perhaps a better title for a book than "Lumber Drying."

In France among various "smoke ovens" the Charpentier stove (preliminary leaching followed by drying in moist air either with natural draught or forced circulation) was patented in 1838. Modern kilns are, of course, in use now, and some odd methods have been promulgated at various times, as electrical heating by conduction, use of ozone gas, high vacuum, and so forth.

As might be expected, early German and Austrian patents are mostly for desiccation by chemical means and the effect of chemicals on shrinkage and other properties. As in France, very modern types are in use now, especially prefabricated and transportable kilns, such as the Standard and Moore Dry Kiln Companies and others produce in this country. Also, the use of superheated steam (low superheat, high velocity) has come into use. In recent years Germany has gone ahead of this country in the theory of drying, as evidenced by some very technical books on the subject. Russia has also published technical books, but prior to 1865, the author has no records.

In countries such as Spain, Italy, South Africa, Philippines, India, Japan, and those of South America, kiln drying is of only recent origin. In Sweden, Norway, and Finland, careful air drying has been the practice until recently when modern kilns have been introduced.

Although the three fundamental principles, proper circulation, humidity, and temperature, were incorporated in many of these early designs, as well as some of the coordinate features, many of them were forgotten or neglected for a long time in later years.

In the United States interest in kiln drying began to develop about the end of the Civil War and the opening up of the transcontinental railways. The first patents were taken out at this time, one in 1862 and four in 1866. By far the most rapid progress was made in this country. Over 300 U. S. patents have been granted for kilns for drying lumber, not including accessories as apparatus, construction materials, instruments, and so forth.

Brain Storm on Drying Methods

As to methods of drying, almost every conceivable operation has been thought of and tried. For instance:

1. Use of a "vacuum" and radiant heat (Forselles, France; Friberg "Hogvacuum-pump," Sweden).
2. Alternate heating in air followed by vacuum (Howard process 1893; Alex. Gray 1904; Tiemann 1909).
3. Alternate pressure steaming and vacuum (Vulcanizing, Fish patents 1920).
4. Steaming under pressure, then exposure to outside air (Kraetzer Cylinder).
5. Superheated steam or air at very high temperatures (British, Symington 1844 and U. S. Lain and Jewett kiln and "AWICO" 1907)..
6. Superheated steam at atmospheric pressure and low superheat, at high velocity (Tiemann 1917).
7. Oscillating temperature and humidity (National "Moistat" and other kilns).
8. Organic vapor (hydrocarbon vapor that condenses to liquid when cooled by the lumber-Monie Hudson process. Taylor-Colquit Co.)
9. Centrifuging by rapidly spinning the pile and causing high circulation of air (Marks, National Air Dryers, Inc., British 1921, and Craig 1923; and in U. S. Craig 1926 and Alexander 1926).
10. Boiling under oil or other hydrophobic liquid.
11. Submerging in hygroscopic salts which extract the moisture. ("Salt seasoning").
12. Injection with volatile liquids or gases to bring about chemical changes and extract the gums (Albert Hermann).
13. Replacement of water by volatile liquid to reduce its vapor pressure, as ether or alcohol.
14. Impregnation with substances that reduce shrinkage and thus permit more severe drying ("Powell" sugar treatment in England and Australia, "Su-Dex" in America).
15. Drying in exhaust fuel or other reducing gases.
16. Drying in highly oxidizing gas (by Ozone, Otto patent France 1917).
17. Low-temperature, high-velocity air.
18. In large chambers normal temperature and periodically moving lumber piles (West Coast for redwood).
19. Platen or accordian driers (Nichols, Veneer).
20. Chain or belt conveyor (especially veneer driers) and "accordian" platens.
21. Rotary cylinders (Leeds & Northrup Co. 1945).
22. Coating with substance to prevent rapid surface drying. (Thelen patent).
23. Leaching under water as preliminary treatment to improve qualities (Japan; Janka's tests 1904).
24. Burying in sand or under ground (Cumberland Method, England 1720).
25. Preliminary squeezing out of free water by pressure.
26. Heating by electrical conduction and possible ionization of some of the water (Nodon-Brettaneaux, France).
27. High frequency electrical diathermic heating of interior. By far the most rapid drying of any process. First tried in Russia and then by the writer in this country. (In U. S. Columbia high-frequency process "for laminated bent forms").
28. End drying short units such as bundles of pencil slats thus eliminating crosswise gradients and stresses (Tiemann).
29. Drying by radiant heat (infra-red) (mostly varnish dryers).
30. Drying frozen wet wood, while frozen.

The author has experimented with all of these 30 methods. From time to time there have sprung up many curious and bizarre apparatus designs for lumber drying, a few of which have embraced features of value. The majority have petered out or proved impracticable. Failure in a commercial process, however, does not necessarily imply that the principles involved were wrong. Some were technically absurd, but others contained excellent ideas that were impractical for economic reasons.

Physical Behavior and Mechanical Operation

In presenting "highlights" in the development of kiln drying, it is necessary to consider the subject under at least two distinct categories: 1) the physical behavior of the wood itself, and 2) the mechanical operation of the drying apparatus. Although it is impracticable to handle the two phases

completely separately, the distinction must always be kept in mind, because the design and operation of a kiln is always dependent upon the behavior of the timber to be dried. An attempt in a general way to handle the two categories in respective order will be made.

From the physical standpoint, the discovery of the *"fiber-saturation point"* was probably the most important factor, because it differentiated between "free water" and "hygroscopic moisture." This was discovered at the Yale Forest School Laboratory, during research on the "Effect of Moisture on the Strength of Wood," in 1902–6. The results are published in F. S. Bulletin 106, and in Circular 108. The bearing of the FSP on drying schedules is of fundamental significance, especially in relation to shrinkage, collapse, honeycombing, set, and casehardening. The difference between sap- and heartwood, pervious and impervious wood is likewise of fundamental importance to the mechanics of the drying operation, but the origin of the knowledge cannot be pointed out as it has come about gradually. "Set," "casehardening," and "compression-shrinkage" were not understood or appreciated until recent experimental work at the U. S. Forest Products Laboratory determined their significance.

Collapse was first discovered by H. E. McKenzie and the author while kiln drying California blue gem (eucalyptus) in a water spray kiln at Berkeley in 1912. Its effects, however, were independently recognized in Australia prior to 1920 by J. Grant, who also found out how to restore the trouble by steaming. The true cause of the phenomenon, however, was not generally understood.

The cause of collapse, which the author worked out both theoretically and experimentally, is due to water tension produced by evaporation from molecular interstices in the cell walls, and the tension stress extends through the free water of completely filled lumina of impervious cells. This tension may run up to thousands of pounds per square inch. It is the same kind of phenomenon that draws water to the tops of tall trees! As the free water passes out, the cell walls are drawn together. It is not due to a "vacuum" as sometimes stated, for one atmospheric pressure would be far too little to collapse the cells.

Collapse occurs only in the removal of the free water from impervious cells when there are no air bubbles, while the wood is above its FSP. It is the main cause of "honeycombing" or "washboarding." In fact, except in the formation of "bottleneck" checks from surface checking, honeycombing is probably entirely due to collapse and not to casehardening as popularly supposed.

"Set" and "compression shrinkage" have also been thoroughly studied for many years at the Forest Products Laboratory and especially by H. E. McKenzie at the Laboratory of the Brunswick, Balke, Collander Co. at Muskegon. Loughborough also did exhaustive research on the effects of chemicals on transfusion of moisture and its relation to all the physical properties of wood and to kiln drying.

Mechanical Process of Drying—Highlights

Circulation is produced in several ways:—natural gravity currents by condensers and ventilators; forced, by steam jets, by external blowers or fans, by internal fans, by multiple fans on a single shaft with baffle deflectors and periodically reversible circulation.

Natural gravity circulation of heated air and such has been used from time immemorial as in the "smoke kilns" already mentioned, and recently in the Paine and Jobert (New Orleans) progressive kilns, which have chimneys at one end with graduated openings, and in their "porcupine" kiln (1906–7). A drier quite similar to early smoke kilns was patented by McNeile in 1874. It used CO_2 gas and water vapor. One of the earliest moist-air-steam-pipe kilns was patented in Australia in 1866 by Trowbridge of Ballarot. Timber was first subjected to live steam "until all the natural sap is drawn out," then "thoroughly dried" by the heat of steam pipes within the kiln.

A natural draught kiln was patented by J. H. Morton in England in 1902, and a progressive kiln in the U. S. by Green and Gerard the same year somewhat similar to the former Standard natural draught types.

Condensers—Recirculation of the air by gravity currents within the kiln and gradual removal of excess moisture was accomplished by use of condensers in 1873 by Edwards, and in 1882 by Whedon. These were similar to the types patented by Perkins and Andrews in 1906, and in Britain and U. S. in 1912.

Perhaps the most notable example of this type was the Andrews kiln, originally a varnish drier, patented by Morton and Andrews in 1890 and 1899, and improved by C. J. Maurel. It had condensing pipes on the two side walls, and an open flue between the lumber above the heating pipes in the center. This was used even in progressive kilns.

Another much-used condensing kiln, as previously mentioned, was that of E. E. Perkins, patented in 1906 and 1912. The condensers and heating pipes, however, unlike the Andrews, were wrongly placed for proper circulation. They disregarded entirely the downward tendency of the air through drying lumber, especially damp or green lumber.

Humidity Control—Half a century ago, little attention was paid to the accurate application of humidity in dry kilns for lumber. A rough kind of control was had in the Emerson kiln patented in England in 1894, which had automatic compression dampers in chimneys in the side walls. This was patented in the U. S. in 1895–96. The principle was that the internal pressure built up because of the evaporation from the lumber would open the dampers and release a certain amount of moist air until balance was again restored.

Some degree of high humidity at the beginning, with a gradual decrease toward the end of the drying, was attained by the Grand Rapids progressive kiln. The chimneys at the charge end were evacuated by a steam jet aspirator, which extracted the cold damp air from beneath the piles of cold lumber, and supplied fresh air to the top of the hot piles at the dry end by means of flues in the walls. These were commercially used in 1913 and patented in the U. S. by Lain in the same year. An earlier kiln that extracted cooled air beneath the lumber by means of chimneys was patented in England in 1853 by Holmes.

The early National kiln had chimneys along the side walls with openings on the inside adjustably graduated at three heights above the rails to control humidity. Before 1921, the American Radiator Co. varnish driers had some humidity added. Before 1920 Drying Systems, Inc., who specialized in varnish driers and many kinds of materials other than lumber, claimed to use completely conditioned heated air, humidified and filtered.

None of these early lumber kilns however, had any degree of accurate humidity control. Not until over 300 Water Spray Kilns were used to dry all kinds of war materials was accurately controlled humidity perfected.

Internal fans were used in England in a kiln patented in 1891 by Phillips. They were used in the U. S. before 1912 in the Cutler kiln, which was patented in England in 1913, and in the U. S. in 1914 and 1920. Multiple fans on a single shaft, as in the present Moore kiln, were devised by Rolf Thelen and patented in 1923. Reversible Circulation was attained in the writer's superheated steam kiln in 1910 and patented in 1918, and in an internal fan kiln developed by Thelen and Tiemann and patented in 1923.

There are various processes of extracting moisture from lumber that are not now in commercial use: diathermic dielectric heating and other electrical methods, centrifuging, alternate pressure and vacuum, and so forth. One combination drying and impregnation process invented by Monie S. Hudson and patented in 1940 has been in extensive use, however. It involves a somewhat different principle than either superheated steam or hot air. In this so-called "organic vapor" drying, timbers (notably railroad ties) are heated in an organic vapor such as toluene, which boils at 234° F., at a temperature considerably above the boiling point of water. The vapor condenses to a liquid when cooled by contact with the timber. Then liquid flows down, and in condensing, fresh vapor is drawn in. The drying is necessarily above the boiling point of water, because the organic liquid must be above that temperature to remain a vapor. Creosote or other preservative is run in the cylinder as the vapor condenses. This process has been in use for some time in New Zealand and in the Taylor-Colquit plant and others in the U. S.

Instruments, apparatus, building materials, and methods of handling the lumber fall in still a third category and no attempt to dwell specifically on these has been made.

Advances have been great in the last 35 years, largely due to better internal circulation, especially by use of internal fans, but also because of improvements in control apparatus and handling equipment. The fundamental principles involved, however, have not changed since they were set forth over 40 years ago in the book on "The Kiln Drying of Lumber" by the author.

Resume of Essential Requirements

The important features are chiefly the following: suitable circulation with prevention of eddy-currents and stagnation; attention to the natural tendency of air to descend through piles of damp green lumber due to cooling by evaporation; periodic reversal of direction of circulation; proper regulation and control of wet-bulb depression and limiting temperatures; elimination of stresses by conditioning treatments with equalization of moisture content; and restoration of collapsed material.

In recent years, emphasis has been placed on economics of operation, and also higher temperatures and to "low-superheat steam high velocity," the latter notably in Germany. Prefabricated transportable kilns have also come into use, both in Europe and here. With present knowledge and equipment, one can make no mistake today in installing any reputable modern make of kiln.

In closing, there is one fact that should be highlighted: Although substitutes for lumber have greatly multiplied in recent years, wood is exclusively the product of Nature by means of the green leaf. It cannot be made by man. Indeed, were it not for Nature's miracle of photosynthesis by means of leaves, no man or animal would be in existence today; for all food without exception is produced in this way.

FACTORS INVOLVED IN

Lumber Packaging for Rail Shipment[1]

J. Buchalter
Material Handling Engineer, Central Development Dep't,
Weyerhaeuser Timber Co., Longview, Wash.

Ultimately, retailers will demand lumber in one package size, in height and width, and one method of mechanical loading and unloading. Availability of proper boxcars and other factors involved are discussed. A proposed method of loading lumber in 1.5 hours is described and compared to the Boise-Cascade, Fowler, McCracken, and hoist-and-chain systems.

Discussions with lumber retailers, wholesalers, and lumber manufacturers indicate that there is considerable interest in boxcar loading. Retailers are discovering that, in relation to other building material receiving activities, the unloading of lumber is proportionately the greatest in cost. This reduces the profit margin. Personnel used to unload lumber from a boxcar can be employed more profitably in selling or delivering products to customers. If temporary labor is used, the retailer is worse off because this type of labor usually does not have the same attitude toward work as does permanent help.

The lumber retailer is constantly reminded of excessive costs by strap or truck sellers, who try to demonstrate the reasons why unitized lumber loading should be fostered. They point out that shingles, nails, and other building supplies can be obtained in unitized shipment.

Few mills are physically equipped and laid out to begin a packaging program without considerable changes and alterations in present loading facilities and the purchase of expensive material handling equipment.

Since the war, lumber mills have made great strides in the automation and quality control of lumber processing. At the lumber shipping area, however, the manual loading methods employed are surprising. Until the past few years, concentrated effort has not been put into unitizing lumber and coordinating this unitizing with the needs of the retailer. When one approaches the shipping area, the role of tradition in manufacturing and selling must be understood. Old methods and practices are handed down as tradition.

[1] Presented at Session XIV, Lumber Manufacturing, FPRS 12th National Meeting, June 25–27, 1958, in Madison, Wis.

The Author: Joe Buchalter holds a BS in mechanical engineering from the University of California, and did graduate work at Stanford. Before joining Weyerhaeuser in 1956, he was in charge of material handling for the Pacific Coast plants of Continental Can Co.

The Weyerhaeuser Timber Co. has built much of their sales volume on the basis that any retailer can have as many items as desired in any particular car. This traditional practice multiplies problems in setting up a lumber packaging program.

In establishing a packaging program, it is necessary to have the cooperation of most of the mills and most of the retailers or it will fail. All mills service all retailers, and few mills supply over 50 per cent of the items bought by any one retailer. Retailers obtain lumber from many mills and want one package size in height and width, and one method of mechanical unloading.

Railroad Cars

One of the biggest factors in considering a packaging program is the railroad boxcar situation. The Timber Engineering Co. published, in November of 1956, a well-documented pamphlet on the quantities of each size and type of railroad car of the 29 major railroads in the United States and Canada. Their figures show that approximately 89 percent of all boxcars in the United States and Canada have six-foot-wide doorways. If consideration is being given to any volume of packaged lumber shipment, one must be limited by this factor.

The railroads are building more and more cars with 14 to 20 foot doorways, but it will be a long time until the supply catches up with the demand. Several other types of boxcars have been constructed for easy access with fork lift trucks. There is no question that these cars are desirable. It is doubtful, however, whether the railroads would ever build them in sufficient quantities to meet the demand.

Package Size

Personnel at Weyerhaeuser realize that a package must fit comfortably through a six foot doorway, must have the ability to be transported by straddle carrier trucks, lift trucks, and overhead cranes, without loss of quantity per load transported. From the lumber retailer's standpoint, four items must be considered. Is the package of a board foot quantity that the average retailer would purchase? Will a combination of package sizes fit the standard-size flat-bed delivery truck in all states? Can the retailer handle the proposed package, without having to purchase expensive material handling equipment? Is this package in such a quantity as to be resaleable by the retail dealer?

The two-foot-wide by two-foot-high (McCracken) package, which will be discussed later, appears to qualify on all counts.

Packaging Problems

The packaging of lumber can be placed in two categories. The first is dimension and boards and the second is the upper grades, or finish lumber. The problems in the first category are considerably less than in the second. Dimension can be packaged one length to the load, which reduces the packaging problems considerably.

When considering the packaging of finish lumber, one finds the problem of shorts. Rule 15, Standard Grading and Dressing Rules, states the maximum amount of short lengths that can be included with each thousand board feet shipped. In making a resaleable package for the retailer, the only choice is to splice the short lengths into each package of lumber. In this way, the mill will be able to dispose of their shorts and the retailer has a good chance of being able to do the same. It is then necessary to calculate the quantity of short lengths to splice with the long lengths to fill out the package, without having any voids. To keep the mill and yard inventories from becoming more complicated, voids in the package should be kept to a minimum. The splicing combination and quantities of shorts must be calculated for each length of package. Weyerhaeuser feels that a minimum-length saleable package of uppers is 14 feet.

Packaging Areas

In pacakaging uppers, an area must be selected for the package to be made up. How it is made up to obtain the greatest economy of packaging labor and material is another problem. After careful analysis, it was found that the most economical operation was to package from the planer chain in the planing mill. Here, packages made up from lumber pulled directly from the planer chain could be transported by overhead crane to the package strapping area. It was found that four packages could be assembled in each pull bin. There would be two packages wide and two packages high with a tee separator to separate the packages vertically and two horizontal separators to separate the packages side by each. All splicing of short lengths with long lengths would be performed by the lumber pullers as packages are being made up in the pull bin.

A prime question is, how much packaging can a mill do? Few mills could package from a planer chain without disrupting production. Customer's orders are so varied that the number of times equipment would have to be changed over to fulfill an order makes the packaging of lumber on a small scale impractical.

An alternative, when packaging lumber on a small scale, is to package from a re-sort chain. This does not tie up production or equipment. The last resort is to package in the Shipping Department by hand. This multiplicity of handling is prohibitive, unless remuneration per thousand board feet can be obtained from the retailer.

Choice of Strapping

There are two choices in strapping steel strap and steel galvanized wire. Either will do the job. Each can be applied with automatic or semi-automatic equipment, or hand tools. There is equipment to tie wire around a package automatically without requiring any manual labor. With the upper grades of lumber, corner protectors are required. There are, however, no automatic corner protector positioners on the market. This then requires that manual labor be in attendance to position the corner protectors, which nullifies the automatic feature of strapping. The type of strapping equipment used is dependent on the speed at which packages have to be strapped.

Warehousing

The two-foot-wide by two-foot-high package is adaptable to the present overhead-crane storing system. Two packages high and two packages wide with vertical and horizontal separators can be tiered in storage with a minimum loss of storage space. If storage is to be maintained with a fork-lift truck, the same set of circumstances apply as with an overhead-crane system.

The difficult procedure, when using an overhead crane, is the removal from storage of a single package. The crane grab is designed to pick up a four-foot width of stacked lumber. At Weyerhaeuser, it is a maximum of two packages wide. This might cause concern to those whose crane utilization is now very high. On the other hand, a lift truck will have no difficulty with stacking one or more packages from a tier of packages.

Boxcar Loading

A major problem confronting the lumber industry is the loading of packaged lumber in boxcars. Several methods have been conceived to load lumber through six-foot-wide doorways, but none have been proven to be the panacea as yet.

A model constructed by Weyerhaeuser employs the use of an overhead electric hoist with rails within and outside of the car. On timber supports on the outside of the car, is a set of fixed rails on which is suspended a set of movable rails. Located on the movable rails is an electric hoist, which is also mobile. The moveable rails or boom slides forward and longitudinally in the boxcar. The hoist transfers from this boom to the bridge. Running lengthwise in the car, next to the side walls, are aluminum rails that are supported by rough 2 by 4's. Each 2 by 4 has a wood block nailed into the top of it. The length of the 2 by 4 is toe-nailed against the side wall of the car. Two blocks are nailed against either side, and three blocks are nailed around the base of the 2 by 4 at floor level. On top of the 2 by 4, a 4-inch aluminum H–beam is placed on its web. Twelve vertical 2 by 4's are placed against the sides of the car, six per side. There are 3 lengths of aluminum H–beams per side. Two 13-foot lengths are at each end with an 8-foot length spliced across the doorway. Placed on the aluminum rails is the aluminum bridge, which runs longitudinally the length of these rails. All of this is assembled into the car prior to loading. The lumber package is picked up, outside of the car, with an electric hoist. It is pushed manually to the car door, where it is transferred to the bridge, inside of the car. The bridge is moved longitudinally to the area in the car where it is desired to place the packaged lumber. After the car has been loaded, the aluminum bridge and rails are removed.

The package-loaded car is forwarded to the retailer, who has the same exact equipment at his yard. He replaces the aluminum H–beam rails by sliding them on their web, on top of the blocks which are fastened to the tops of 2 x 4 supports, along the side wall. The bridge, which is made in two halves, is lifted on top of the loaded packaged lumber and then onto the rails. The two halves of bridge are spliced, after the aluminum rails are spliced across the doorway. After he has unloaded the car, the rails and bridge are removed by the retailer.

A prototype of this mechanical handling device has not yet been constructed the main reason being that it is a highly specialized piece of equipment and it has a singular function. Preferred is a multi-purpose piece of equipment, like a fork-lift truck.

Several methods use a fork-lift truck. The Boise-Cascade method employs loading with a lift truck through a wide-door boxcar. The Boise-Cascade package is two feet high and four feet wide. The quantity of board feet per package is greater than the average dealer will buy, on a consistent basis. This method is the fastest for loading and unloading, but still leaves the problem of wide-door boxcar availability.

The Fowler method, which is being publicized by the Signode Steel Strapping Co., uses a cantilevered lift truck with a welded pipe boom attached to the forks. There has been a certain amount of success with this equipment. There is a fixture on the end of the boom that swivels 360 degrees. There is a roller arrangement approximately 3 feet from the lift-truck mast that allows additional latitude when positioning the package in the car. The boom is driven into the car at an angle and the packaged lumber is pushed and swiveled into place.

The McCracken System, conceived by Mr. Jim McCracken of Leechburg, Pennsylvania, has considerable merit and should be scrutinized closely as to its use with dimension and boards. It will not work on finish, with the present method of bundling. The system is based on a mathematical equation that establishes a positive number of the same length pieces of lumber in a unit, (which he calls a module) and whose foot length becomes the decimal or 1/10 of its board foot value. Thus, to determine the board feet in one module package, simply multiply its foot length by 10. For a package twice the size, in height, multiply by 20 and so forth.

McCracken also employs a boom attached to the forks of a lift truck for boxcar loading and unloading. The boom is 10 feet long with a "U" shaped shovel that swivels 360 degrees at the end. The shovel is designed to fit two-unit or four-unit packages.

Weyerhaeuser is in the process of designing a modification of the boom loading operation, that it is hoped, will give more flexibility to the combination boom and fork-lift truck operation.

Labor and Material Cost

There is no question that making up and strapping packages will increase the cost of marketing lumber, at first. At the present time, compensation is obtained from the retail dealer, who is willing to expend these funds for the ability of being able to unload lumber mechanically. One retail dealer in Chicago has unloaded a car of 30,000 board feet in 16 minutes by the Boise-Cascade method. This is the extreme. Most dealers are happy to unload in one and one-half hours by the same method. Again, this is the large, two-foot-high by four-foot-wide package that does not have too much appeal to the average small retail dealer.

In time, the mechanical methods of loading will help to offset the mill's additional cost of packaging.

Lumber pick up and loading costs average between $1.75 and $2.00 per M board feet. To perform the same operation and in addition band, load mechanically, and bulkhead by hand costs approximately $3.50 to $4.00 per M board feet for labor and material. If mechanical equipment is employed for package make up as well as for boxcar loading, it is possible to approach and possibly surpass the present hand-method cost.

It has been stated that less than 30 per cent of the lumber retailers in the United States have fork-lift truck equipment. The small retailer who takes two or three cars per month is not very likely to spend $6,000 for a fork-lift truck. His amortization period is too great to make it practical. It is quite possible that these retailers will never be interested in unitized car loading.

It may cost the retailer $6,000 but it will most likely cost the large mill 20 times that amount, depending on how much change and alteration is necessary to the present physical layout of the mill. This cost includes the purchase of additional material handling equipment as well as powered package conveying and strapping equipment. One can readily see why mills are not rushing into the packaging of lumber without being fairly certain that the system is workable, has a good chance of being adopted by the lumber industry, as a whole, and is acceptable to the retail dealer.

Summary

There are a number of factors that must be considered when undertaking a lumber packaging program. There are considerably more factors for the mill than for the retailer, since the mill must initiate and adapt to fit the program. Any program must be a cooperative effort between mills, and between mills and retailers. Anything less than this will retard and work toward the detriment of the program.

Although there are several methods of loading packages through a six foot door, none has been the complete answer to the problem of mechanical loading. The economical packaging of uppers and the problem of mixed cars are the two greatest problems confronting the mills at the present time.

In the final analysis, the package size must be one that is resaleable by the retailer, and must be in a board foot quantity that is normally purchased by the average retailer.

A PROGRESS REPORT ON

Laminating in Canada

R. F. DEGRACE

Executive Vice-President, Canadian Institute of Timber Construction, Ottawa, Ontario

There are still many questions to be answered, but industry growth has been good. Self-imposed manufacturing control administered by CITC keeps quality high.

THE FIRST PLANTS engaged in commercial laminating in Canada primarily produced light rafters for agricultural use; some factories manufactured sawn timber trusses. Truss chords and auxiliary building members were occasionally laminated. In 1950, the production of glulam arches, beams, and other structural parts was begun on a commercial scale.

The production of structural glulam has grown until now ten major and several small fabricators are operating plants in five of Canada's ten provinces. Their combined covered floor space is in excess of 350,000 square feet, and their estimated production capacity is more than 50 million board feet per year.

The dollar volume in non-agricultural glulam increased 53 per cent in the year ending September 30, 1957, over the year ending September 30, 1956, but all non-residential construction showed an increase of about 22 per cent. During these same periods, glulam production capacity increased by more than two-thirds.

In 1953, a committee of the Canadian Standards Association (CSA) drew up Specification 0122 for the Design and Fabrication of Glued Laminated Structural Timber. The committee members did not feel that American specifications could be adopted directly, because of differences in the grading rules and the need for providing for all Canadian species.

The adopted specification was extremely flexible in its application. It took a theoretical approach, which would permit a limitless number of combinations of laminating grades, and left it up to the designer to calculate the working stresses for the combinations selected. Three methods of manufacture also entered into the calculation for working stresses. Fabricators could develop working stresses for the particular species, grades, and methods of manufacture that they found most practical. The methods required, however, were awkward and discouraged design by independent engineers.

At about the same time, the 1953 edition of the National Building Code of Canada was nearing completion. In the section on Wood Design, the provisions of CSA Specification 0122 were included. Before the Code was published, the provisions included in all preliminary drafts for modifying working stresses for various durations of anticipated load were deleted. This gave rise to serious objection from the timber industry. The National Building Code, however, reconsidered the deletion when revisions to the Code were made. After two years of study it was decided that the principle of modifying working stresses with duration of load applied to timber and that essentially the provisions recommended by the committee who drafted the section should be adopted. This section is now being revised, and will incorporate these principles.

Engineering Design for Timber

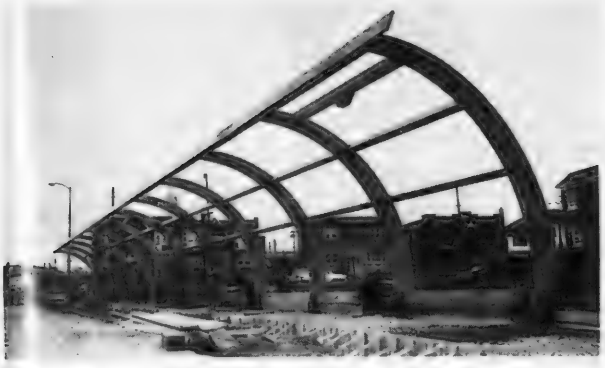
To establish improved and permanent specifications, a CSA committee on Engineering Design in Timber was formed to draw up a specification for design, similar in nature of the National Design Specification of the National Lumber Manufacturers Assoc. During the past three years, the committee has developed this specification to its final draft form.

An important simplification has been the listing of Canadian species into four groups, with the strength properties for the group instead of for the species being tabulated. The same grouping has been used for working stresses in sawn timber and glulam, for timber connectors, and for other fastenings such as bolts and nails.

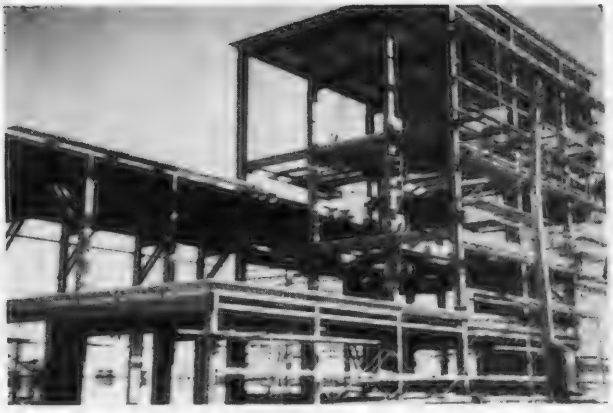
Simplification of glulam working stresses called for more drastic measures. The U. S. Forest Products Laboratory had published in 1954 a statistical approach to the determination of working stresses for various combinations of grades of lumber. The method called for the sampling and mapping of typical laminating stock to determine the frequency of occurrence of knots in each grade. Calculations based on mathematical indicators of known frequency could then be made to determine working stresses for any specified grade combination.

The Canadian Institute of Timber

[1] Presented at the 1958 Wood Industries Conference (Joint meeting, FPRS Eastern Canadian and Northeast Sections and Wood Industries Div., ASME) Syracuse, N. Y., March 31–April 1, 1958.



Simplicity and utility are joined in this functional Montreal transportation shelter of Douglas-fir glulam.



Multi-story glulam. structure for a uranium mine in northern Canada.

Construction made arrangements to carry out such a knot-frequency study. Several hundred pieces of laminating stock were selected at random from the supplies of four laminating plants, two located in western Canada and two in the east. The location and size of each knot was mapped. This information was then tabulated and the calculations were carried out according to the method developed by the U. S. Forest Products Laboratory.

At this point, however, a departure was made from American practice. In the working stresses issued by various regional lumber associations in the United States, two sets, usually for the range from 4 to 14 laminations, and for 15 laminations and more, were given. These data were in addition given for each of about 15 different grade combinations.

In Canada, certain stress levels were selected and from the curves plotted, grades required for each stress level were determined. Several possible combinations of grades might result in the same stress level for a given number of laminations, and the choice could be made by the laminator.

To put this scheme into practice, all laminators met and decided which stress levels should be published. A combination of grades that might be efficient in bending might be relatively inefficient in compression, and vice versa. After a large number of possible combinations were considered, four were selected; one in bending, two in compression, and one in tension. These were labeled 24f, 20c, 18c, and 26t; the number indicates the first two digits of the working stress at normal duration of load.

To provide working stresses for other species, an auxiliary table of factors was worked out by which working stresses could be assigned to equivalent stress grade in other species. By this means, very extensive tables were reduced to only four lines and the minimum number of columns required to describe the strength properties of the material, with another similar four-group table for conversion to other species.

At the same time that stress levels were selected, the laminators determined those grade combinations that should be published (from those available), and also determined the strength properties of the stress grade. The minimum grades required for various numbers of laminations can then be tabulated in CSA 0122, which will become the standard reference for the manufacturer and will be of no concern whatever to the structural designer. A complete set of adhesive specifications will eventually be required, as will application specifications for how an adhesive shall be used.

Revision of the National Building Code of Canada section on Wood Design has been postponed pending completion of the CSA specifications and the new approach. It has been generally agreed that the resultant provisions in both documents be the same, although they might differ in details of arrangement or presentation.

Research Studies

In addition to the knot-frequency studies, other research was necessary to develop complete and experimentally justified specification requirements. Stepped scarf joints had been developed so the thickness of the lamination at end joints would be the same at other points in the lamination. It is known that such stepped scarfs are lower in strength than plain scarfs. (U.S.F.P.L. Tech. Bull. #1069). A study on the subject by the U. S. Forest Products Laboratory did not give any specific information on the reduction in strength of stepped scarf joints as a result of stress concentration, beyond considering the stepped portion ineffective in calculating the moment of inertia.

Preliminary tests carried out on full-size beams at the Forest Products Laboratory at Ottawa indicated that the reduction in strength of such joints was greater than calculations by rational means alone would determine. Accordingly, a series of tests was carried on at the University of Toronto to determine the stress-raising effect of steps in scarfs[3]. More than a thousand tests were made, and these were continued and extended in scope at the Ottawa Laboratory. The results showed that the step at the tip of a scarf joint creates a reduction of strength in tension substantially greater than would be calculated by considering the discontinuity of fibers alone. This reduction is the result of a stress concentration at the tip, and varies regularly with the thickness of the tip. The hook usually placed at the midpoint of a stepped scarf joint had little or no effect. Other information secured was that the strength of commercially made scarf joints was slightly less than that determined for laboratory-made scarfs reported in the USFPL study, and that the type of glue used had no significant effect on strength.

These tests were further extended in 1956 at the University of Alberta. The same scarf joints were placed in small beams and tested to failure in bending. Comparison was made with control beams with no scarfs and with controls where the tension lamination was isolated from the others, with no glue line providing support. The results confirmed the pure tension tests previously made, although the effect was not so marked in bending as in pure tension. As a result, a table of scarf-joint strength ratios for both stepped and plain scarfs was completed for inclusion in the revised version of CSA Specification 0122.

Another problem was the effect of the placement of scarf joints in a mem-

[3] Results of this study by S. P. Fox were published in the Oct. 1956 FOREST PRODUCTS JOURNAL.

ber upon strength. Interpretations of existing data always called for spacing of scarf joints in adjacent laminations at 24 times their thickness, although the original recommendation for this figure was not fully documented. The University of Alberta was selected to explore this question. The most severe cases likely to occur were selected and compared with unjointed control beams. It was thought that the most severe cases would be beams with a scarf joint at the most highly stressed section in every lamination; and other critical cases would be scarf joints lined up "heel-to-toe" in adjacent laminations, thereby creating planes of possible weakness.

The beams with a joint in every lamination were fully as strong as those that had a joint only in the bottom lamination. Both of these compared as expected with unjointed control beams. The "heel-to-toe" beams did not show lower strength, either. More than 120 beams were tested in the series. Therefore, although it is desirable that scarf joints be "well scattered," no mandatory controls on their position in a beam was thought necessary.

An onerous provision in the 1953 CSA Specification was that "scarf joints shall be made in clear wood". Trying to find 19 inches of absolutely clear wood without cutting laminating stock into expensive short lengths often resulted in discarding quantities of otherwise perfectly good laminating stock. A search of literature and corespondence with the U. S. Laboratory did not elicit any usable information.

A study in cooperation with the Forest Products Laboratories of Canada was set up. After much discussion, it was decided to select from commercial laminating stock pieces with a knot of the right size in the right place, so that there would be enough material for side-matching for controls. A great deal of lumber was turned over, but the specimens were found, and the tests were carried out. Although the vast quantity of tests necessary to an absolute determination have not been practically possible, the number of tests have been great enough to determine that the effect of knots permissible for the grade appears not to be significant to scarf joint strength.

Making the Designers' Work Easier

In March of 1953, the author suggested in a paper given at the Eastern Canadian Section of the Forest Products Research Society that a vital need for the commercial extension of the use of glulam was a manual of timber construction, which would place within one set of covers all the engineering data needed to design structures in glulam, possibility by a then non-existent organization. Both ideas have borne fruit. The Canadian Institute of Timber Construction (CITC) was organized and for the past two years, has had in preparation a Manual of Timber Construction.

To be published in early 1959, the manual contains in curves and tables the design specifications set forth in CSA specifications and in the National Building Code of Canada. The manual and new CSA Specifications will be published at about the same time.

Industry Control of Quality

An additional need in the industry has been for some assurance of quality of workmanship. This need was brought home to Canadian laminators as small firms came into the business, sometimes without adequate background and knowledge. Revision drafts of the National Building Code of Canada require that manufacturers of glulam must be qualified to the satisfaction of the administrative official, and CITC was asked to prepare standards suitable for such qualification.

Fortunately, the need was seen by the industry at an early date, and the laminators set about preparing such a standard. The result, after more than two years of study and revision, has been the Qualification Code for Application to Manufacturers of Structural Glued-Laminated Timber, a CITC standard.

The Qualification Code is administered by a board of three, who pass upon reports made by an Examiner employed by the Institute. Initial examination is comprehensive, covering the physical plant and equipment both for manufacture and quality control, the procedures adopted by the plant for manufacturing, and the personnel for supervision of manufacture and for quality control. Plants found to be qualified are permitted to attach a label to their products, and to issue a certificate attesting to manufacture according to the Code. Reexamination without warning, is required at intervals of about six months.

Plants are required to manufacture according to applicable CSA Specifications, and may not offer for sale as a structural member any product not acceptable under the Code. All structural products must be designed by a registered professional engineer and so marked upon the drawings. Operating and quality control procedures are rigidly controlled.

The manufacturer must develop a set of Manufacturing Standards for his own plant, setting forth the procedures to be followed in the operation. The scope of the standards is clearly set forth in the Code. The examiner then reviews these standards and assures that the procedures are actually being followed in the plant.

Three classes of qualification are covered. Class I (Interior), glulam for building construction, with casein or similar glues; Class XS (Exterior Softwoods), waterproof glue manufacture for structures such as bridges; and Class XH (Exterior Hardwoods), the more rigid manufacturing required for shipbuilding. The classes show only the class of work for which the plant is equipped. Some plants may be qualified in all three classifications, others in only one.

One requirement of the Code is that the head of the quality control department must report directly to management, and not to the plant superintendent. This assures that plant operations can never overrule quality control. Another requirement calls for equipment arranged so that "positive mechanical positioning is employed in the assembly of end joints to eliminate possibiltiy of human error in meeting and maintaining the required tolerance". The examiner must assure that the performance required by the Code is met by the manufacturer.

This Code was placed in operation in September, 1958. Since it is entirely voluntary, its success will depend upon the acceptance and use made of it by those designing and writing specifications for glulam construction.

Future Development

A stronger sales effort is needed if the industry is to compete with other structural materials whose sales effort is greater than that of timber.

From the research point of view, there are many questions that still need answering. More work on scarf joints should be carried out. Other types of end joints call for further investigation if waste of material is to be reduced. Deeper studies are needed on manufacturing procedures, and here the cooperation of adhesive suppliers is necessary.

A problem peculiar to eastern Canada is the economical use of two species in a glulam member. If this can be successfully and economically accomplished in production (the use of strong Douglas-fir in outer laminations and weaker but less expensive eastern species in the inner laminations), the result will be a composite member, which will be more economical from the point of view of material than the equivalent member designed in either species alone. The design methods need study, and confirming research should be carried out for the domestic species that can be used.

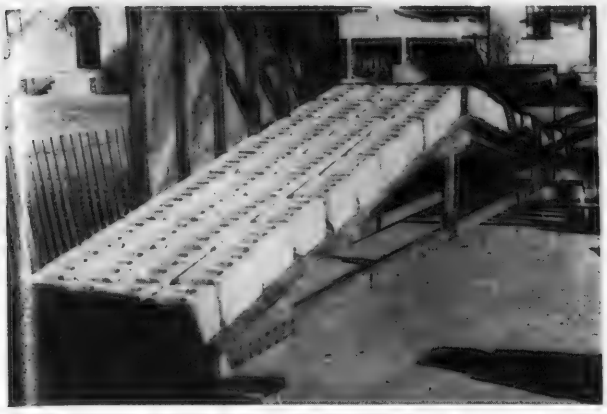


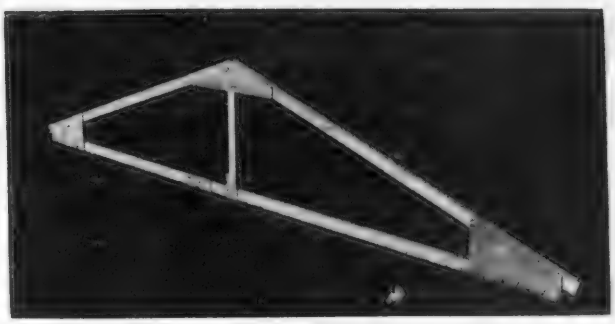
Fig. 1.—A pair of king-post trusses under 40 psf load exposed to actual atmospheric changes.

Fig. 2.—A 28 foot 8 inch nail-glued hiproof under load of 10 psf for 19 months.

DURABLE STRUCTURAL COMPONENTS OF Casein Nail-Glued Wood[1]

D. H. Percival
Research Assistant, Small Homes Council,
University of Illinois, Champaign

Casein glue, after laboratory and actual open exposure testing, is recommended by the author as the glue best adapted to the fabrication of the nail-glued truss. Under 40 psf roof load, glue in interior-plywood gusset plates deteriorated while the casein remained intact.



The use of glue in residential building has increased considerably in recent years. Various components of a house may be fabricated with glue as the structural assembly material. Bonding skin covering to studs, fastening plywood gusset plates to truss chords, and gluing window members to frames are a few examples. So far, however, fabrication with glue has been restricted to controlled shop conditions.

The chemical life of the glue, the durability of the glue bond, the strength of the glued joints, and other such information about glue are of concern to contractors, the home owner, and the financial lending agencies.

At the Small Homes Council, full-size structural components are being and have been built and tested to determine their mechanical properties under both short-term and long-term loading. For example, roof trusses are loaded with concrete blocks to simulate loads such as accumulated snow. Deflection readings are obtained. The Council also makes a long-term load test on the trusses that covers a period of 120 days. This would seem to be a severe test period; however, there are no universally accepted long-term tests for a component such as a truss.

Casein Glue

After many laboratory tests to determine the best all-around glue casein was selected for nail-gluing in truss construction[2].Casein glue is a mixture of milk, protein, lime, and other ingredients. It can be purchased for about 34 cents a pound directly from the manufacturers. This price will vary with quantity. The casein recommended for nail-gluing structural components must pass Federal Specification MMM–A–125 Type I or Type II (a specification for water resistant qualities).

Casein glue is not new. There are authentic recorded examples of the durability of casein glue in the construction of laminated arches in Europe. This method of lamination is known as the "Hetzer system". The use of casein glue in these arches began in 1913 in Denmark. T. R. C. Wilson, of the U. S. Forest Products Laboratory, observed these structures and reported that no collapse or serious glue delamination was evident.[3] in structures varying in age up to 25 years.

Full-Scale Truss Tests

Full-scale, nail-glued truss structures under design load of four feet of simulated snow in the form of concrete blocks would seem to be a severe structural test for glue bonds when exposed to actual outside changing climatic conditions. Accumulations of four feet of snow on a house roof in most areas of the country would be highly improbable. Exposure to extreme cycles

[1] A contributed paper received March 15, 1954.

[2] Granum, H., and B. M. Radcliffe. 1954. Design of nail-glued plywood gusset plates and solid wood splice plates for softwood. Bulletin 613, Agr. Exp. Sta. Purdue Univ.

[3] Wilson, T. R. C. 1939. The glued laminated wooden arch. U. S. Forest Prod. Lab. Government Printing Office, Washington 25, D. C.

Fig. 3.—Extreme bending of the top chords shows heavy loads sustained by the glued units.

of wet and dry conditions is also improbable within a properly vented attic. A condition most detrimental to a non-waterproof glue bond would be the presence of moisture in sufficient quantities to break down the glue and to create conditions for mold growth.

Nail-Glued King-Post Truss Set-Up

A pair of 24-foot, king-post trusses, 2/12 slope, spaced 24 inches o.c., is shown in Fig. 1. No protection was provided for the roof sheathing. These trusses were constructed in December of 1955, according to the Small Homes Council instruction sheet A.I.A. 19b 3(g). Used in their fabrication were 5/16 inch, C–D unsanded interior grade plywood, 4-penny common nails, and casein glue. The trusses were tested for deflection and strength characteristics, after which they were stored under cover until September, 1957, when they were again set up and subjected to a design load of 40 pounds per square foot. Observation of the plywood gusset plates (after 13 months of exposure) indicated no apparent delamination in the casein glue joints and only slight delamination in the glue bonds of the plywood. These trusses will remain under load as long as they continue to support this load.

Nail-Glued Hip-Roof, 24-Foot Span

A nail-glued hip-roof set-up was tested for deflection and strength properties. The clear span of the hip-roof was 24 feet with a slope of 3/12. The structural chords were No. 1 grade 2 by 4 inch. The gusset plates were 5/16 inch, C–D unsanded, interior-grade plywood. Casein glue and 4d common nails were used in assembling the trusses. A simulated snow load of 40 pounds per square foot, in the form of concrete blocks, was applied to this nail-glued roof system. It was erected in July 1956 and dismantled in September 1957, a period of 14 months. Plywood delamination was developing, but no evidence of failure in the casein glue bond was observed. Again, no protection was provided for the roof.

Nail-Glued Hip-Roof, 28-Foot Span

Another nail-glued hip-roof, 28 foot clear span, was tested for deflection and strength properties (Fig. 2). This system is capable of spanning 28 feet without interior supports.[4] The deflection average for the trusses in the hip-roof was 0.41 inch under a design load of 40 pounds per square foot. A deflection in excess of

$$\frac{\text{span length} \times 12 \text{ inches}}{360}$$

is considered maximum to prevent plaster cracking. No 1 grade, 2 by 6 inch chords were used as the joists and 2 by 4's were used as the rafters. The gusset plates were 5/16 inch, C–D unsanded, interior-grade plywood. Casein glue and 4-penny common nails were used for the connections. Observation of the set-up after 19 months indicated some extensive localized plywood delamination. A few casein glue joints showed only a slight beginning of break-down where the joints were completely exposed to the rain. The hip-roof remained under 40 pounds load per square foot from July 1956 to January 22, 1958. Extreme bending of the upper chords may be seen in Fig. 3.

Between January 21 and January 23, 1958, the plywood at the center lower joint of the first truss failed in the plywood glue line. This failure occurred as a result of the delamination of the interior glue used in the plywood. None of the casein glue joints failed, even though water had occasionally been retained in pockets as a result of the inherent characteristics of the truss design. Fig. 4 shows the slippage that occurred in the interior glue between the layers of the plywood.

A chain reaction occurred when the bottom chord of the first truss hit the concrete floor. Rupture occurred in the top chord, which resulted in a load transfer to the adjacent trusses. Subsequent plywood delamination brought about collapse of the adjacent trusses with similar rupture of the top chords. Again, observation of the entire structure showed no casein glue joint failure. The use of exterior-grade plywood would have prevented the delamination in the plywood glue bond with a resultant longer life for the structure.

Nail-Glued Test Beams

Six sets of 4-foot beams, severed at the center, were reassembled by nail-gluing 5/16 inch, C–D unsanded, interior-grade plywood as splice plates. Various nails and staples supplied the clamping pressure for the glue.

[4] Small Homes Council. 1956. 3/12 slope, nail-glued hip-roof system, working sheet. Small Homes Council, Univ. of Illinois.

Fig. 4.—Slippage as a result of plywood glue failure between the layers of the plywood.

In four of the test set-ups, 4-penny common nails were used. An additional set was staple-glued, and in the sixth set, the nails were removed after the glue had cured. Each of these set-ups were subjected to a total of 1040 pounds. These beams were loaded in October 1956, inside a building, then moved outside in April 1957, to the present location. Observation of the glue lines, in October 1958, showed slight delamination of the plywood but, as yet, no failure of the casein glue joints.

Summary

The application characteristics of casein glue as a structural assembly material appear to be suitable, but its durability for a long period of time is questionable. Several examples of the structural capabilities and durability of casein glue connections under design load with changing climatic conditions have been presented. These components, under test, were exposed to actual climatic changes from wet to dry and from hot to cold for periods of from 13 to 19 months. Delamination of the hip-roof plywood gusset plates at the center lower chord joint was excessive, and slippage in the plywood laminates then caused failure. The interior plywood, an accepted material for dry, sufficiently ventilated attics, failed while the casein bonds were still intact. An actual occurrence of extreme moisture in the form of rain and snow, radical temperature changes, and roof loads of 40 pounds per square foot for this length of time are far in excess of conditions to be expected in a house.

The results of this study indicate that:

1) Casein nail-glued bonds, properly made with the specified glue, would be entirely adequate for structural components that are in dry, properly ventilated structures.

2) Further durability in nail-glued components can be obtained by increasing the specifications to include only MMM-A-125 Type II glue (mold inhibitor added) and exterior-type plywood.

Portable Chipper Used for Forest Thinning, Developed in Sweden

Transportable chipper operation for forest thinning.

Temporary chip storage in the field.

Feed mechanism on the chipper.

Small Trees and Bushes Transformed into Chips

A transportable chipper constructed by AB Maskinfabriken, Sweden, has been used to clean up forest areas, the firm reports. In an operation carried out in cooperation with the Forest Owners Assoc. of örnskōldsvik, bushes and small trees were transformed into chips with all the branches on. About 185 acres were cleaned and 3600 cu. m. of chips were produced.

The capacity of the chipper varied between 40 and 70 cu. m. per day. Studies by the Swedish Central Laboratory of the Wallboard and Pulp Industries found the quality of the chips good for the manufacture of wallboard and pulp. The waste after screening was 1.4 per cent in reference to weight.

Two models of the chipper are made that have 350 and 600 cu. ft. per hour capacity, respectively. The gross weight of the machines are 5800 and 8400 lbs. The machines are also designed for cutting slabs, lathes and other wastes. They can be mounted either on a 2-wheel trailer truck or on a 4-wheel truck.

Other Developments Around the World

FAD

Industrial Wood Needs Rise Throughout World

There is every evidence that the world can produce 2,000 million cubic meters of industrial wood annually (its estimated requirements by the end of this century), the Food and Agricultural Organization (FAO) of the United Nations reported recently.

"In the past decade, the world's industrial wood requirements have risen from 589 to 917 million cubic meters per year," FAO said. This tendency is expected to continue, although at a reduced pace. FAO reported that forest industries in many areas have established efficient and prudent utilization to insure a steady supply of raw material for the future.

The use of wood as fuel is declining in Europe and North America, FAO reported, but this is still its most important use in Latin America, Asia, and Africa.

Scanning World Wide Forest Products Publications

Germany

Comparative Investigations with Different Isolates of *Lentinus lepideus*, a Contribution to the Soil-Block Method. Georg Schulz. *Holz a. R. uW.* V. 16, No. 11, (In German)

Twenty five different isolates of *Lentinus lepideus* were tested according to the American Soil-block Method and also partly according to the German, "Klötzchen-Verfahren" (DIN 52176) for their destroying capacity to different species of wood and for their tolerance to 3 wood preservatives. The following facts were found.

There are great differences in the behavior of the isolates with regard to unprotected as well as to impregnated wood.

A great destructive capacity of the fungus on untreated wood does not infer off hand a great tolerance against wood preservatives.

The majority of the isolates are suitable for investigations of the natural decay resistance of woods as well as for wood preservative tests in the laboratory.

According to the growth of mycelium, certain "types" with a considerably different destructive intensity could be found among the 25 isolates.

On the Mechanics of the Multi-layer Particle Board. Rudolph Keylwerth, *Holz a. R. uW.* V. 16, No. 11, (In German)

With a view to the economic importance of multi-layer sandwich boards and plastic layer boards from wood base materials their physical and mechanical principles are explained and, taking three-layer particle boards as example, compared with experimental results in their application.

The determination of the thickness of surface layers on particle boards and the control of their variance by statistical methods is described. With the obtained mean value of the thickness of the surface layer the shelling ratio of three-layer boards can be laid down in numbers, which is necessary for calculating the resulting properties of the whole board from the properties of its individual layers.

These connections are examined with reference to density, moisture content, resin content, modulus of elasticity, shear modulus of elasticity, stress and strain characteristics, tensile, compression, bending and tensile strength across the board. As was to be anticipated, the most characteristic property of a good three-layer board is a relatively high bending and shearing stiffness. As this favorable shelling effect for the use properties of the board is obtained the more completely, the better is the construction of the board (shelling effect, density of the layers) and the elastic properties of the layers are adjusted to each other.

Examination of Filled Glues. Werner Clad. *Holz al. R. uW.* V. 16, No. 10, (In German)

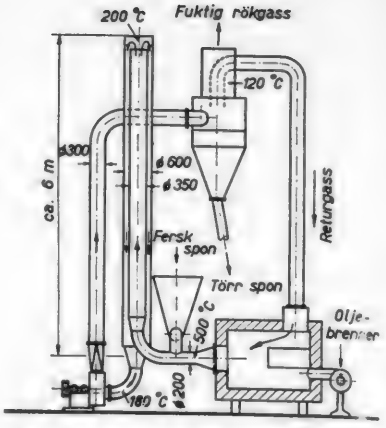
This examination of filled glues shows the relations between the kind of glue and filling shrinkage of the glue, thickness of the glue line, and the resulting firmness of the line. The examination of different kinds of glues proved that only filled glues with small shrinkage are suitable for lines over 0.5 mm. Simultaneous tests with unfilled glues clearly demonstrated that the sensibility is highest after using cold-curing phenolic resins; aminoplastes closely follow, urea formaldehydes being more sensible than dicyandiamite formaldehydes, whereas epoxide resins are not sensible at all. The different test methods were examined on their suitability. The author concludes by recommending a test specimen according to DIN 52364, which can at the same time be used for investigating the exact curing time. In the writer's opinion, the examination of the tensile strength perpendicular to the surface—particularly with unfilled glues—plays a much greater part than the determination of the shear strength.

Norway

Investigations on Methods of Sawdust Drying. P. Granlund. *Norsk Skogindustri.* Vol. 12, No. 11. (In Norwegian)

This article discusses some results of investigations undertaken by 3 methods of drying sawdust: steam drum drying, flue-gas drum drying, and suspension drying (flash drying). All three methods were highly usable, but the initial cost of drum dryers is high as compared with a suspension dryer, and the measured heat consumption by drum dryers did not indicate any advantage over the suspension dryer. (Which of the three methods is preferred is dependent on the local circumstances).

To study the drying effect of a suspension dryer, a pilot plant was built by the Norwegian Institute of Wood Working and Wood Technology (Norsk Treteknisk Institutt). Although suspension sawdust dryers are used in other countries, only scattered information was available regarding the performance of this system for drying sawdust. Investigations were therefore carried out with the object of providing a basis for designing suspension dryers. It is concluded that a suspension dryer preferably should



be designed for the following operating efficiency:

Gas inlet temperature ---500–600 C
Gas exit temperature ----115–125 C
Gas flue-rate in vertical ducts ---------- 8–10 m/s
Gas flue-rate in horizontal inlet zone ---------- 25–30 m/s

A design based on this data is shown in Fig. 1. With conditions mentioned above, this dryer has a normal capacity of 250 kg/h dried sawdust (10 per cent) from an initial moisture of 100 per cent (based on dry weight.)

Statistical Considerations on the Variation in Maximal Volumetric Swelling in Pine Wood *(Pinus silvestris* L.) Julius Boutelje. Holz. a. R. *uW.* V. 16, No. 11, (In German)

The paper reports on the relations between maximal volumetric swelling and different characteristics in some wood samples. The multiple regression analysis of swelling jointly with density and age from the pith shows a negative regression coefficient for age in the sapwood sample. This is possibly caused by the increasing width of the annual rings out to the periphery of the sample trees. In the other samples, consisting of specimens taken over the total distance from the pith or from the heartwood of the sample trees, no significant correlation between swelling and age was obtained. A graphical representation of data shows no correlation between percentage of summerwood and the ratio of volumetric swelling to density. Extraction of resin substances does not seem to affect essentially the hygroscopical changes in volume. In this connection it is doubted that resin penetrates into the cell wall during heartwood formation as often is mentioned. Consequently, differences in swelling values between heartwood and sapwood seem to arise from other causes.

Contributions to Wood Preserving Techniques—Part V: Investigations on the Practical Application of the Bored Holes Pressure Method for the Impregnation of Timber. Werner Baverdamm and Udo Siuts. *Holz a. R. uW.* V. 16, No. 11. (In German)

In routine tests, pressure treatment in bored holes with the so-called Springer-pressure vessel was proved in connection with air-dry and moist pine and spruce. Thereby the absorption of preservatives and the penetration depth of four water-borne and two oily preservatives were investigated. The results showed that cold oils, because of their low viscosity, are not suitable for this kind of impregnation. Among the salt-mixtures the bifluoride-agent may be considered the best, as a partly complete penetration of the wood, even pine heartwood, could be observed. The results with pine are more favorable than with spruce. The preservatives are chiefly diffused in longitudinal direction. General directions for use cannot be given. However, a distance of 19.7 in. with spruce and 39.4 in. with pine between the pressure vessels is recommended. Compared with the single bored holes method, pressure treatment shows several advantages.

Fiberboard Panel Discussion[1]

Wood Fiber for Packaging

C. E. Swanson

Wood Conversion Co.,
St. Paul, Minn.

Insulation board has found its best use in the packaging industry as interior blocking, positioning, and cushioning to insure safe transit and storage of both commercial and military goods.

Fiberboard is limited by virtue of its high density to the packaging of heavier items that are not delicate. To cushion more fragile objects adequately, softer, lower density, more resilient products must be used. Tufflex, a Wood Conversion Co. product, and Kimpac, a Kimberly-Clark product, fall into this category.

Tufflex is a 100 per cent wood fiber product. It is representative of a group of about 7,000 individual products each designed to meet certain end-use requirements. The modifications concerned in this group are various thicknesses (1/8 inch to 3 inches), various densities (1/5 to 4 pounds), various binding agents, special treatments (water resistance, water absorption, fire retardance), surface treatments, and backing materials. Such complexity of a product line may be questioned, but consider some packaging requirements and how they can be met.

Asparagus, when packaged, will continue to grow if offered an adequate supply of water. This growth, if timed right, maintains freshness and tenderness in the asparagus stalk. Shipments of asparagus are made in wood crates with the stalks packed in an upright position standing on a wood fiber pad. After packing, the loaded crates are dipped in a hydrocooler. The purpose of the pad is to cushion the base of the stalk to protect it from bruising, and to maintain an available supply of water and chemicals.

The shipment of small gasoline samples, liquid pharmaceuticals, and cosmetics requires adequate and absorptive cushioning. If the container should break, the entire quantity of liquid should be retained in the package for the protection of adjacent articles. In these applications, the hygroscopic nature of the wood fibers is a definite advantage.

Metal items that may be stored for long periods of time need cushioning that resists moisture absorption to avoid corrosion. In insulated packages of cold colored film, plastics, resins, live lobsters, fresh frozen meat, and produce, where the media acts as a cushion and an insulation, the moisture absorption should be minimum because of moisture's effect on insulation "k" values.

At an electronics plant, the packaging engineer is faced with the packaging of delicate ceramic discs that weigh a few grains and are used as insulators, test panels weighing 200 pounds, and even completed electronic brains that weigh thousands of pounds. The variety of weights to be handled necessitates a versatile product for cushioning.

There is a full spectrum of fragilities to contend with, almost indestructible stainless steel bars or silver ingots, fragile baby chicks, fluorescent tubes, hard but brittle candy, laboratory glassware, electronic equipment, and so forth.

Requirements are compounded by the necessity of designing products that not only meet or exceed the required cushioning but are also adaptable to prefabrication and use. Certain fragilities and end-use requirements necessitate the use of other cushioning materials such as rubberized hair and plastic and rubber foams.

The packaging industry represents a total of about 8 to 9 billion dollars per year, with probably 90 million dollars of that for cushioning materials. The U. S. Air Force alone estimates they spend more than 1/2 billion dollars a year on packaging, and perhaps 20 million dollars of that is for interior cushioning.

An important facet in packaging is that users have accepted the concept that a packaging material is a necessary production item, which will cushion and protect them in transportation and handling, and also be functional by meeting requirements other than those of basic cushioning.

The Need for New Fiberboards

George Chamberlin

Minnesota and Ontario Paper Co.,
International Falls, Minn.

The greatest use of fiberboards at present is in the construction industry. In this industry, areas that appear to offer the greatest potential new market growth are semi-hardboards (or medium-density fiberboards), and sandwich panels. The increasing costs and lowering quality levels of wood and plywood combined with industry's increasing ability to build in special properties at necessary levels is creating a new market for semi-hardboard products. The potential as cores in the furniture and sandwich panels alone is enormous.

The use of sandwich panels of prefabricated sections for construction has been in an explosive state. Curtain walls and partition walls in office buildings and factories are going up made out of almost every conceivable combination. Stainless steel, aluminized steel, porcelain enameled steel, copper sheet, aluminum and glass plates, plastic skins and hardboard faces, corrugated paper, paper honeycomb to hollow core and solid fiberboards, and so forth.

The rush to use these panel constructions is based on some very sound advantages. They 1) save time of erection and thus labor cost and equipment required; 2) permit greater flexibility in design and arrangement; 3) save space—thinner in cross section; 4) are light weight, permitting less expensive foundations and eased loads on structural members; 5) little finishing; 6) less maintenance; and 7) a few even have fire resistance.

Some interesting panel constructions can and are being made entirely of fiberboards, but the industry should

[1] This series of papers was part of a panel discussion presented at the Upper Mississippi Valley Section meeting, Aug. 15, 1957, at International Falls, Minn.

strive for the realistic and eventual products that will use a combination of the best materials to obtain the maximum benefit of their outstanding characteristics. Sheets of foamed plastic, paper honeycombs, and other materials should be evaluated to see whether they can be integrated with present or potential products.

The rather sudden return to a competitive fiberboard market, brought about by increased capacity and temporary slump of home construction, has pointed out the necessity of refining or changing methods of developing new fiberboard products. During and after the war, all one had to do was bring out a product with somewhat different characteristics and let the customer adapt it to his own use. With the return of competition, a specific product must be designed for each market or customer. This tailoring will bring more market stability, but requires increased research and technical service. Small markets or potential customers won't justify this expense, but large present or potential markets not only justify it, but will undoubtedly require it.

We will have to strengthen our techniques for determining what qualities are needed for each use. The customers' opinions should be checked, and realistic performance tests must be developed. We must not accept accelerated performance tests that exaggerate some action far beyond some use conditions, and then measure and correlate these new performance tests with actual use performance. With realistic yardsticks for necessary or desired quality established, straight forward research can then determine whether desired characteristics can be built into a product economically.

Fiberboard for Interior Finishing

D. B. Anderson

Wood Conversion Co.,
St. Paul, Minn.

As interior finish, *board* (that is large sheets), *plank* and *tile* in the dominant thickness of 1/2 inch are used. These finish items are about 1/3 of the total industry production.

Building board is a general-purpose structural insulating board normally supplied in 1/2-inch-thick square edge sheets, 4 feet wide and in lengths of 8, 10, and 12 feet. It is used for walls and ceilings with predecorated, factory-finished surface exposed, or as a base for paints, wall coverings, or other finishes. A factory-finished, utility-type wallboard in 5/16 or 3/8 inch thickness, 4 foot widths, and 8 and 10 foot lengths is also available.

Insulating board with a factory-applied paint finish is fabricated in the form of plank and tile for use as a decorative interior finish in all types of building construction. Planks are made in 8, 12 and 16 inch widths and in 8 and 10 foot lengths. Tile is produced in 12 by 12 inch, 12 by 24 inch, 16 by 16 inch, and 16 by 32 inch sizes.

The sound absorption value of tile is increased by drilling or by other means of perforating the surface. Perforated tile is usually produced in 12 by 12 inch and 12 by 24 inch sizes.

Plank, plain tile, and perforated tile are furnished with butt joints or with specially fabricated interlocking edges that permit blind stapling, clipping, nailing to furring strips, or cementing to solid backing. The products are equally adaptable for new work or remodeling old interiors. As a material for remodeling in the home, it can be used in a wide variety of pleasing designs and may be applied directly over the old surfaces.

Boards are generally applied by nailing to framing or furring members spaced on 12 inch or 16 inch centers. The insulating boards should be nailed 6 inches apart first to intermediate framing members and then 3 inches apart along the edges. For exposed nailing, finishing nails, brads or painted nails should be used. Where joints are to be covered with batten strips or moldings, common nails can be used.

Interior board and wallboard may be used as is. If other effects are desired, oil, varnish, or water-emulsion paints may be applied directly to the surface.

It is particularly important that the framing or furring for tile and perforated tile carefully conform to the size of the units used. For 12 by 12 inch and 12 by 24 inch units, 12 inch spacing is satisfactory. For 16 by 16 inch and 16 by 32 inch units, 16 inch spacing may be used but 8 inch spacing results in superior application. The units may also be applied by cementing to continuous smooth surfaces. Furring strips for planks should be at right angles to the plank spaced on 9 inch centers up to a height of 5 feet, and 12 inch or 16 inch centers above this height.

Most plank, tile, and perforated tile are made with fabricated joints that allow for concealed nailing or stapling. They are fastened with either 1 inch large-headed nails such as box nails, or 9/16 inch staples. Some manufacturers have developed a special clip system and interlocking joints for installing plank, tile, and perforated tile.

A large quantity of perforated acoustical tile is applied by acoustical contractors or "applicators" in accordance with specific application instructions developed for particular end uses of the product. It is generally applied by one of three methods: cementing to solid surfaces; by nailing, screwing or stapling to wood furring strips; or by mechanical suspension systems.

Experience With NuPly

Russell Eggers

NuPly Corp.
Bemidji, Minn.

The NuPly Corp. makes only a board with two smooth sides, and the firm has gone after the market where this is an advantage. At one time, the use of hardboard was thought to be a cheap substitute for other products, while now users are buying it because of its appearance. The display and toy industries are examples of users to whom the appearance of both sides of the board is important. For some furniture parts, the smooth two sides board has opened a broader field.

When used on a vertical surface, the smoothness of the reverse side reduces the tendency to collect dust, either inside or outside of an enclosure, and this is of interest to many users. The use of hardboard as an element in the manufacture of laminated products is steadily increasing, which makes good gluing properties desirable.

Many of the newer users demand properties that are somewhat different from the standard board or panel board. It may be increased water resistance, better stability, higher strength or impact resistance, or less porosity. The industry cannot be static. New uses and requirements are constantly increasing, and ideas and research are needed if the industry is to hold its own in the face of competitive materials.

CONSULTING SERVICE

Consultant engineers with headquarters in Caracas, Venezuela, specialized in tropical forestry and wood utilization. Surveys on marketing, forest inventories, plant designs, and new uses of tropical woods. Write to

CONSULTANT ENGINEERS
Apartado del Este 4575
CARACAS, VENEZUELA

Unit Car Loading

J. Brelsford, W. H. Patterson, and Steele Barnett, Boise Cascade Corp., Boise, Idaho, Presented at a meeting of the Inland Empire Section and the Northwest Wood Products Clinic, April 16, 1958 at Spokane, Wash.

For the past four years, the Boise Cascade Corp. has been experimenting with the unit loading of double-door box cars. This system of loading has the advantage of low unloading costs in the retail yards. During 1957, the first year that the firm shipped unit-loaded box cars, 565 cars were shipped with a total footage of over 20 million feet. The minimum unloading time for a single car of 36,000 feet was about 16 minutes, with an average maximum time of 1½ hours.

Unit car loading was conceived as a result of inquiries for a type of load that could be mechanically unloaded. A meeting with the Weyerhaeuser Sales Co. and retail dealers interested in this type of shipment led to adoption of a standard size unit that was a nominal 48 inches wide, 32 4/4 boards high, or 16 dimension boards high.

At first, the units were built and banded inside the car, but this proved to be prohibitive in cost, as well as unsatisfactory in arrival condition. The units were then banded outside the car and loaded by means of a 7,000-pound lift truck, operating from the shipping dock to the inside of the car. Because an excessive amount of interlacing developed between the units, eight stickers, 1 inch by 2 inches by 4 feet, were placed in each unit in two diamond-shaped patterns running crosswise through its length.

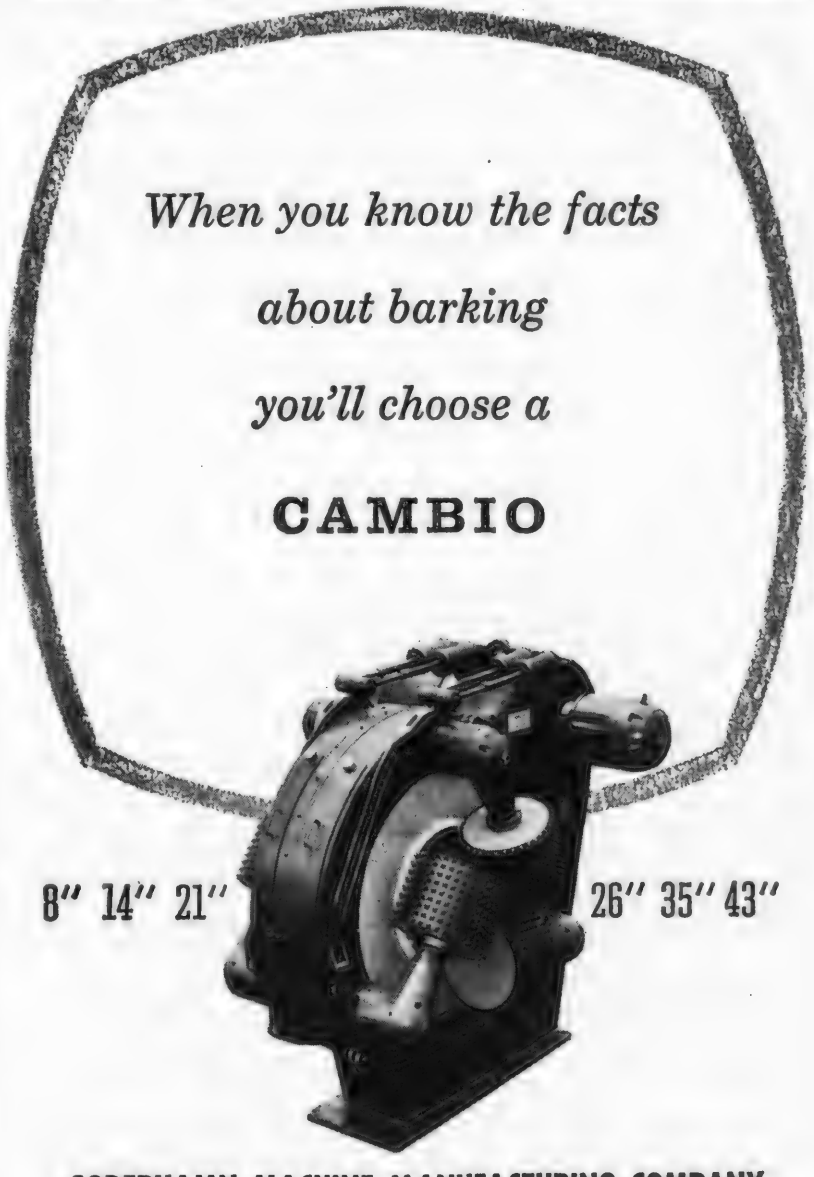
A special hydraulic press was designed and constructed which places vertical and horizontal pressure on the unit throughout the entire banding operation so that an absolutely compact unit is developed. Two 1½ by 0.035 steel straps are placed around the unit in line with the stickers and are automatically tensioned.

In almost all cases, the longer units are placed in the end of the car. Three of these are positioned in the doorway, one on top of the other on a specially designed dolly and separated by 3 by 4 inch spacers. The entire tier of three units is then bound together with two 1¼ inch by 0.035 steel bands interlaced through the bottom one third of the bottom unit, and the top one third of the top unit.

For ease in unloading, it was decided that lengths not more than 4 feet longer than the width of the door would be loaded, except for 20-foot lengths in cars with 15-foot door openings. Vertical separators are placed between the ends of the bottom units in each tier to eliminate the chance of interlacing. To prevent longitudinal movement, a bulkhead is built to the height of the bottom units to fill any void that may occur in the car.

It is possible to unload from either a dock or at ground level. The bulkheads and dunnage are removed from the doorway, and the interlace bands cut. The smaller units are easily removed from the doorway. The longer units are removed from the ends of the car by hydraulically lifting the tier, and inserting a dolly or rollers to facilitate moving to the doorway area. If the units are longer than the width of the door, the fork-lift operator, by making a sharp backward turn, can easily maneuver the unit out of the car.

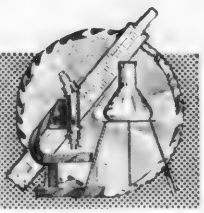
At present, a new hydraulic press is being designed that will virtually conduct the unit construction in a nearly automatic fashion. With the new press, one man will construct and strap the units. Experimental work is also being done on the strapping of random-length units. By nesting the shorter lengths together inside of a unit, it is possible to band a package of approximately 2,000 board feet and not exceed 16 feet in length. This, however, is still in the development stage.



SODERHAMN MACHINE MANUFACTURING COMPANY
Talladega, Alabama
West Coast: 9442 S.W. Barbur Boulevard, Portland, Oregon.
East Canadian Representatives: Forano Limited, Montreal, Canada.

SODERHAMN — FIRST NAME IN WOODWASTE UTILIZATION EQUIPMENT

Abstracting the Literature



Procurement

Anon. Military Handbook — Lumber and Allied Products. Dept. of Army Tech. Manual TM–715–5500–1. Supt. of Documents, U. S. Govt. Printing Office, Washington 25, D. C. 223 pgs. $1.50.

Although the primary purpose of this Handbook is to provide information to assist all branches of the Dept. of Defense in the procurement of lumber, plywood, poles, piling and other wood products, the information contained therein brings together in one place information on the nature of wood and of handling techniques that can either contribute to a very satisfactory product or that can materially reduce its usability and service. The references to Commercial, Military, Federal or other Specifications are helpful, and the section on "End Use Guides for Grade Selection" with its reference to usable species for the different end uses can be useful to procurement agencies other than the military.

Construction

Successful Lu-Re-Co Homes. Lumber Dealers Research Council, Ring Bldg., 18th & M Sts. N.W., Washington 6, D. C., 1957, 15 pp, free

The ten houses shown in this booklet were chosen from a large number of designs which have actually been built with the Lu-Re-Co system. Each house shown was chosen for outstanding qualities which gave it unusual appeal and acceptability. Area of houses ranges from 900 to 1145 sq. ft.; all but one are one story, with the exception being a split-level. [BRI Abstracts, June 1958]

Debarking

Prince, R. D. Tampella Mark II debarker. *Pulp Paper Mag. Can.* 59, no. 5: 169–70 (May, 1958).

Data are given on operations with the Tampella Mark II debarker. The hourly operating cost of the machine, including all the wood handling, is $20.00. For a production ranging from 5 to 7.5 peeled cords/hr., depending on the size of the wood, the cost of debarking runs between $2.65 and 4.00/peeled cord. Costs are further improved when barking wood of 8, 9, or 10-inch average diameter, since the productive capacity of the machine is directly related to the linear feet processed times the average diameter. Some improvements in machine design are suggested. [Bul. Pap. Chem. V. 29, No. 1]

Sawdust

Stewart, Donald L. Mechanical pulp from sawdust. *Pulp Paper Mag. Can.* 59, no. 7: 125–8 (July, 1958); *Paper Trade J.* 142, no. 36: 48–51 (Sept. 8, 1958).

The possibility of using sawdust as a raw material in the production of mechanical pulp was examined. Sawdust can be satisfactorily pulped in a disk refiner to give a pulp resembling groundwood. If the sawdust is not pretreated the power consumption will be about the same as for groundwood of the safe freeness. The pulp will be as strong as groundwood in tear but weaker in burst and tensile. The brightness will be about the same as for groundwood from the same wood supply. A variety of pretreatments were investigated. [Bul. Pap. Chem. V. 29, No. 3]

Wood Drying

Stevens, W. C. The effect of air speed and flow direction on the drying of a pile of timber. *Timber Technology,* Vol. 66, No. 2225, March 1958, pp. 121–3

It has long been known that the effects of air movement in kiln drying are considerable. An increased air speed tends to promote faster heat transfer and moisture evaporation. However, it must be realized that the wood itself sets a limit to the rate at which surface evaporation may take place without detriment to the material. If this limit can be attained by adjusting the humidity of the air entering, there is no advantage in increasing the velocity of the air when dealing with narrow piles of timber. Normally, commercial piles of timber are not narrow in modern kilns. With a pile 7–8 ft wide and with uni-directional air flow, the drying lag can become quite appreciable and a fast air movement between the runs would reduce this to reasonable limits. Unfortunately, the power requirements of fans increase very rapidly with the speed and increasing the velocity of the air might prove to be costly where it is not possible to install large diameter fans.

A cheaper method is to alternate the direction of air flow. That the alternating air flow leads to more uniform drying and a reduced 'lag', as compared with unidirectional air flow, can be shown by the following. After 60 hours of drying when the inlet samples were at 38% moisture content, the wettest samples were at 33% with uni-directional flow, and only at 27% with alternating flow. [F.D.C. Tech. Bul. V. 7, No. 40]

Wood Properties

Kollmann, Franz, and Schneider, Adolf. Devices for the routine and exact scientific measurement of sorption properties of wood and wood-based materials. *Holz Roh- u. Werkstoff* 16, no. 4: 117–22 (April, 1958). [In German; English summary]

The water-vapor sorption of wood and wood products is commonly determined by the gravimetric equilibrium method.

Alternatively, sorption isotherms have been determined from direct measurements of the equilibrium vapor pressure of wood samples *in vacuo*. Two new methods for sorption measurements have been developed. One of these, suitable for practical control and routine determinations, combines the gravimetric equilibrium method with direct vapor-pressure measurements *in vacuo* and requires only 5 days/sorption isotherm. The other method, which permits accurate determinations, including hysteresis curves, to be made over a wide range of temperature on 10 samples simultaneously, is based on the microscope determination of the elongation of quartz-glass springs loaded with the equilibrated wood samples and on the simultaneous manometric determination of the corresponding equilibrium vapor pressure. [Bul. Pap. Chem. V 28, No. 11]

Safety

McCormack, George R. Analysis of logging injuries. [Pulpwood Annual section] *Pulp & Paper* 32, no. 7: 133–6 (July, 1958).

A statistical survey of logging injuries shows no improvements in the accident picture of the logging industry since 1944. Accidents are analyzed by severity, frequency, size of operation, occupations, types of injuries, regional variations, etc.

The preparation of abstracts from world literature in many languages is so highly specialized and costly that the Forest Products Research Society has no abstracting service of its own. For the abstracts in this issue of the JOURNAL the Society is indebted to the respective abstract journals indicated, from which they have been selected with the kind permission of the editors. Readers wishing information in addition to that given in these abstracts should consult the original articles referred to. Copies or additional information can not be supplied by FPRS or the abstract journal. The journals from which abstracts are published in this issue are as follows:

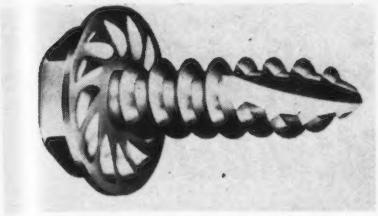
BRI ABSTRACTS OF BUILDING SCIENCE PUBLICATIONS, published for the use of its members, by the Building Research Institute, National Academy of Sciences—National Research Council, 2101 Constitution Avenue, Washington 25, D. C. Over 70 periodicals are reviewed, plus new books and research reports from industrial, governmental, and academic laboratories and organizations.

BULLETIN OF THE INSTITUTE OF PAPER CHEMISTRY, published monthly at Appleton, Wisconsin by the Institute of Paper Chemistry, subscription price $25 per year. This Bulletin publishes over 3,600 abstracts per year on subjects of interest to manufacturers of pulp, paper, fiberboard and allied products.

CHEMICAL ABSTRACTS, published semimonthly by the American Chemical Society, Executive Office—1155 Sixteenth Street, NW, Washington 6, D. C., subscription price $60 per year plus postage. This abstract journal publishes many thousands of abstracts annually with broad coverage of world literature in the entire field of chemistry and allied subjects.

TECHNICAL BULLETIN OF THE FURNITURE DEVELOPMENT COUNCIL is published bimonthly by the Council at 11 Adelphi Terrace, London W. C. 2, England. The Technical Bulletin publishes hundreds of abstracts and reviews from world literature annually, relating to the various phases of the furniture manufacturing industry. Subscription price is $5 per year.

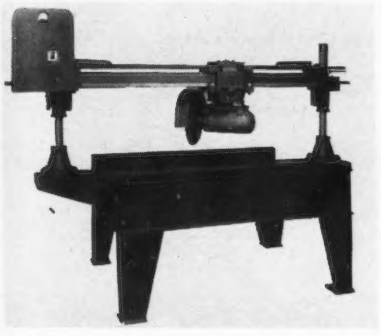
FPRS News–Digest, Continued



Screw That Eliminates Stripping

A screw designed to eliminate stripping as it drills and taps its own hole in soft wood and particle board has been developed by Shake-proof Division, Illnois Tool Works. Called "Type 17 Nibscrew", it has "nibs" under the head to absorb excessive driver torques, and a self-drilling point.

In soft or thin material, the "Nibscrew" reportedly provides braking action by increased stripping torgue two to four times that of regular heads. Additional information is available from Shakeproof Division, Illinois Tool Works, St. Charles Road, Elgin, Illinois.



Swivel-Head Precision Saw

A swivel-head precision saw for composition board and plywood is now being produced by the TY–Sa–Man Machine Co. the new model "144–BD" sells for under $2,000. Cross cutting is achieved by a power screw feed with ten-point ball bearing travel along the machined transverse rails. For ripping long sheets, the swivel-head is turned 90°. Information is available from the Ty–Sa–Man Machine Co., 1060 White Avenue, Knoxville, Tenn.

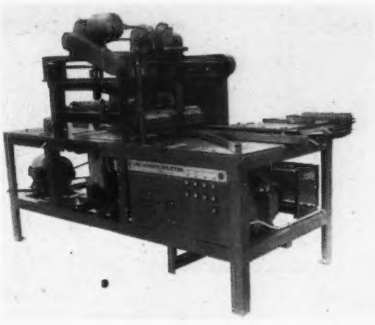
Pamphlet on Glue Spreaders

A new booklet on the Black Brothers roll glue spreaders has recently been released. The Bulletin, "11-A", Part 4, shows installations views of these machines and lists several new optional extras recently made available with the machine. A copy can be obtained from Black Brothers Co., Inc., Mendota, Illinois.

Splitter for Lumber Remanufacture

A lumber splitter to handle over-runs of planed lumber for remanufacture to smaller, more merchandisable stock items, has been announced by the inventor, Marvin Key. According to Key, the machine produces stock with top and bottom eased edges.

In upgrading, Key maintains, the lumber splitter will salvage $20 or more per thousand on over-runs. Stock is fed between powered front press rolls and through top and bottom cutter heads mounted on yokes.



Hollowed splitter knives are used to plane both edges of the lumber simultaneously. The top cutterhead produces the top eased edge of the finished stock. The bottom head performs the splitting action and cuts the bottom eased edge simultaneously by means of a series of splitter knives that alternate with eased edge cutters.

The machine operates at feed rates of up to 400 feet per minute and is tooled to operate with a splitter head that carries as many as 14 knives. It will handle stock ranging in size from 1 by 3 inches minimum to 4 by 24 inches maximum. More information is available from Key Machinery Designers, Inc., First National Bank Building, McMinnville, Ore.

Sharpener for Carbide Tools

A new "Roll-a-Tilt" attachment has been released for the "Grinder-lap" by the Diamond Tool Co. The attachment is used to sharpen brazed-tip carbide saw teeth and router and planer carbide edge knives up to 40° relief angle on tilt slotted table with gauge.

The attachment reportedly gives a 325 screen finish with diamond charged wheel, ½ minute per face per tooth. Can be used for teeth, any angle or size, with 5 inch to 20 inch diameter. More information is available from Sheldon Booth, President, Diamond Tool Co., South Haven, Mich.

What's New in *Technical Publications*

Review of Literature on Bark Adhesion and Mehtods of Facilitating Bark Removal. E. Perem. Reprint from *Pulp and Paper Magazine of Canada.* Available from the Forest Products Laboratories of Canada, Dept. of Northern Affairs and National Resources, Ottawa, Ontario, Canada.

Wood Chipboard Manufacture. 1) machinery for chip preparation; 2) drying and size separation; and 3) storage bins, mixers and feeders. L. Mitlin. The objective of the article is to discuss the fundamental principles of the unit processes, to indicate the various factors that affect the choice of individual plant items, and to describe the different machines on the market.

Forestry Equipment Notes. Nov. 1958. A Catalogue of Mechanical Saws for Felling and Bucking. The equipment is listed according to trade names, manufacturers, and technical specifications. Available from, Chief, Equipment Section, Forestry Division, FAO of the United Nations, Viale delle Terme di Caracalla, Rome, Italy.

The following publications are available free of charge from the U. S. Forest Products Laboratory, North Walnut Street, Madison, Wis.

Angelique. Revised Nov. 1958. B. F. Kukachka. Describes the mechanical, machining, seasoning, and other properties of this foreign wood. Report No. 1787.

Sandwich Panels for Building Construction. L. W. Wood. This report summarizes research at the Forest Products Laboratory on the use of sandwich panels in housing and other buildings. Report No. 2121.

Hardboard from Red Alder and from a Mixture of Slow-Growth Southern Oaks. S. L. Schwartz. Purpose of this study was to demonstrate the suitability of two widely different hardwoods for the production of hardboard, and to note the influence of the degree of hydrolysis on yield, board strength, and sizing efficiency. Report No. 2125.

WILCO REFUSE BURNER

Three Models. Complete Range of Sizes. Lowest-cost installation. Prefabricated, one-piece panels. Exclusive triple-draft. Sizing engineers available to you.

WILCO MACHINE WORKS, INC.
Municipal Airport • Memphis, Tenn.
P. O. Box 3722 • WHitehall 8-4555

YOUR'S FREE . . . FOR SIGNING-UP JUST ONE NEW MEMBER!

Your choice of any FPRS Annual Proceedings for the years 1947 through 1951. These beautiful cloth-bound volumes will make a fine addition to your library. They represent the choice papers presented at FPRS' National Meetings each year. Your Proceedings will be sent to you postpaid anywhere in the world. Help us to get one or more new voting, associate, or supporting members and complete your library soon.

. . . And There's a Bonus for the New Member as Well!

WHEN YOU JOIN FPRS for calendar year 1959 as a *new* member you will receive an *extra* bonus in addition to the regular Society benefits. You, too, may take your choice of any of the above cloth-bound Annual Proceedings for your library.

One of the best ways to keep abreast of the newest and latest in wood technology is by joining FPRS. Just one good idea put to practice in your organization may return your modest membership cost many times. Mail your application *today* and start getting—

1) The outstanding monthly FOREST PRODUCTS JOURNAL.
2) Personalized service on your technical questions.
3) Important contacts with wood experts.
4) Notice of FPRS meetings from coast to coast.
5) And other benefits.

APPLICATION FOR MEMBERSHIP

1959 FOREST PRODUCTS RESEARCH SOCIETY 1959

ADDRESS OF THE EXECUTIVE SECRETARY
417 NORTH WALNUT STREET, MADISON 5, WISCONSIN

(DATE)

TO THE EXECUTIVE BOARD:

I hereby make application for

- ☐ Supporting Membership ($100)
- ☐ Voting Membership ($15)
- ☐ Associate Membership ($15)

} in the Forest Products Research Society, including regular publications of the Society. CHECK ONE (Qualifications defined on reverse of this sheet)

Note: Of $15 or $100 membership, $11.25 is paid for a one year subscription to the FOREST PRODUCTS JOURNAL.

(SIGNATURE)

Please provide *all* of the following information. The Executive Board cannot act on incomplete applications.

YOUR NAME _____ (PRINT OR TYPE)

COMPANY NAME _____

MAILING ADDRESS _____ (STREET)

_____ (CITY) (STATE OR PROVINCE)

NATURE OF BUSINESS _____

APPLICANT'S TITLE OR OCCUPATION _____

NOTE: New Member: Please Check Which Issue You Want FREE for Joining Now:

- ☐ Vol. I 1947 Proceedings,
- ☐ Vol. II 1948 Proceedings,
- ☐ Vol. III 1949 Proceedings,
- ☐ Vol. IV 1950 Proceedings,
- ☐ Vol. V 1951 Proceedings,

NOTE: Regular FPRS Member: Check Which Issue You Want FREE:

- ☐ _____
- ☐ _____
- ☐ _____
- ☐ _____
- ☐ _____

NAME: _____

ADDRESS: _____

NOTE: THIS OFFER DOES *NOT* APPLY TO *STUDENT* MEMBERSHIPS.

Take Your Choice of FPRS Proceedings for Signing-Up One New Member

1947— Vol. 1—UTILIZATION, ENGINEERING, PRESERVATION, SEASONING. 25 papers, 344 pp.

Articles cover: whole wood fiber manufacture; lignin chemistry; processing pine gum; paper and plastic overlays for veneer and plywood: integrated utilization; trends in logging; pulpwood logging developments in eastern Canada; building codes in postwar wood construction; engineering problems in prefabricated homes; postwar packaging field; functional furniture; postwar woodworking glues; metal to wood bonding; high frequency in woodworking; wood finishing; the use of car treated lumber; fence posts; an untapped market for the wood preserver; acid-proofing of wood; the artificial seasoning of wood in vapor of organic chemicals; kiln design; tungsten carbide developments; and tight cooperage plywood. Regular price $6.00

1948— Vol. II—UTILIZATION, FIBER PRODUCTS, BARKING, FINISHES, MACHINERY, R. F. HEATING. 50 papers, 500 pp.

Articles cover: economics of wood-waste utilization; losses in Redwood logging; small log gang sawmill; utilization of low-grade hardwood lumber; wood-distillation industry; sawdust carbonization; animal feeds from wood residue; small wood briquetting machine; special machines for utilization of waste slabs for glued core stock; interior trim from wood waste; wood-fiber production with revolving disk mills; effect of some manufacturing variables on the properties of fiberboard prepared from milled Douglas-Fir; small hydraulic log barker; mechanical methods of bark removal; studies on the chemical composition of bark and its utilization for structural boards; research in industry laboratories; history of furniture finishes; finishes resistant to alcohols and acids; low-bake synthetic finishes; simple testing methods for finishers; planning floor space for woodworking equipment; maintenance and operating practice for tungsten carbide tools. Regular price $8.00

1949—Vol. III—RAW MATERIAL, FURNITURE, PLYWOOD, UTILIZATION, GLUES, SEASONING. 55 papers, 607 pp.

Articles cover: more wood per acre; integrated wood utilization at Crossett; harvesting sawlogs; portable wood chippers; wood fibers from veneer waste; small permanent-type sawmills in better forest utilization; pulpwood handling in the Lake States; tropical wood research for the furniture industry; effect of plywood glue lines on the accuracy of moisture-meter indications; No. 3 common Northern hardwood lumber for mechanized processing into glued products; cut stock from western softwoods; assembly material in furniture manufacture; supplementing wood with metal in furniture manufacturing; extending hot press urea resin with wheat and rye flour; furniture finishes; lumber core panels; rotary veneer cutting; molding plywood; insert-point circular headsaws; ills besetting the furniture industry; utilization of Redwood bark; utilization of waste sulfite liquor in concrete; semichemical pulping; dry-formed boards bonded with resins; wood, plywood and hardboard; compreg-resin-treated densified wood; wood preservatives; wood boring beetles; ignition temperatures of fireproofed wood, untreated sound wood, and untreated decayed wood; wood waste disposal and air pollution control in the Los Angeles area; pulp mill pollution; chemical composition of Ponderosa and Sugar Pine barks; lumber recovery from Douglas Fir logs in British Columbia; resin adhesives; development of working stresses for stress-grade lumber; design and performance of laminated wood trusses; glued laminated wood; glued laminated Wej-weld frames; radio frequency heating. Regular price $8.00

1950—Vol. IV—MILLING, CONTAINERS, QUALITY CONTROL, PLYWOOD. 45 papers, 506 pp.

Articles cover: quality of second growth Douglas Fir; grading problems; quality control and the improved seasoning processes of the Redwood industry; saw teeth in action; lumber research to meet modern competition; hardwood log grading; recent developments in wirebound containers; method of utilizing and fabricating waste lumber; tests of strapped and lightweight lettuce crates; recent developments in containers; papermaking fibrous raw materials; utilization of low-grade hardwoods and softwoods; relation between wood and pulp properties; power vs. hand falling and bucking in logging operations; handling pulpwood; quality control in sawmill operations; hardwood plywood quality control; quality control in furniture production; defect detection equipment; non-destructive testing. Regular price $8.00 Now $2.50

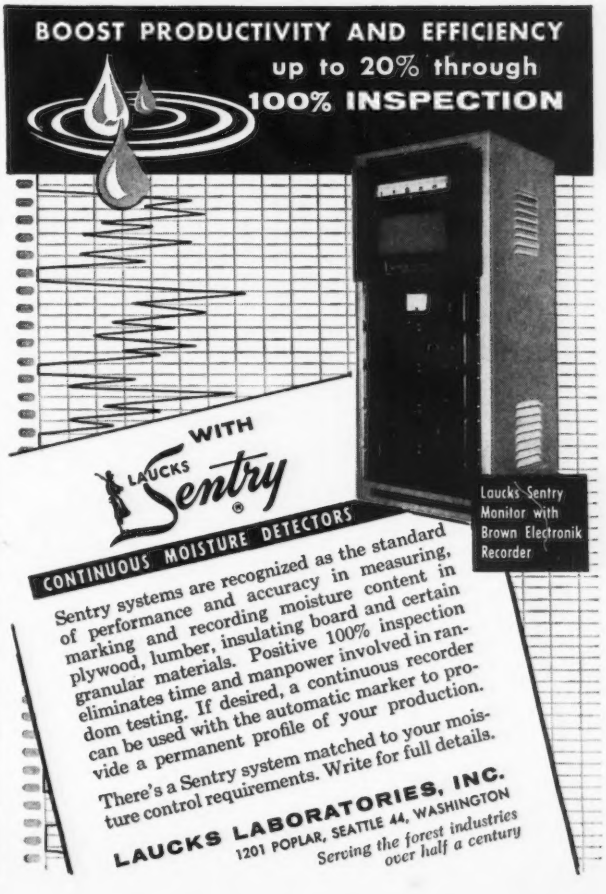
1951—Vol. V—MILLING, MACHINING, PRESERVATION, UTILIZATION, GLUES, KILN DRYING. 51 papers, 400 pp.

Articles cover: circular sawmills in the Tennessee Valley region; quality control in lumber manufacture; gangsaws in the manufacture of southern pine lumber; tropical hardwood production; logging and military equipment availability; defense and the availability of woodworking equipment; the importance of wood in the mobilization program; mobilization requirements for technical men in the woodworking industry; lumber conservation in military procurement and container design; military requirements for wood in packaging; wood requirements for specialized military uses; the place of small business in the military procurement program; marine laminating; selecting White Oak for bending lumber; machinability studies; carbide cutting tools in the wood industry; carbides; fire retardant treated lumber; wood preservation with particular reference to creosote; what the furniture industry expects from college-trained men; the scope and objectives of college training; graduate training in forest products technology. Regular price $10.00

Index to Advertisers

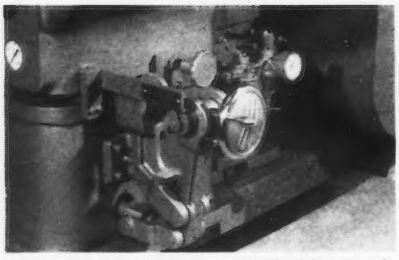
Behr–Manning Co. ---------- 3-A
Buss Machine Works ---------- 2nd cover
Consultant Engineers ---------- 26-A
G. M. Diehl Machine Works ---------- 4th cover
Greenlee Bros. & Co. ---------- 2-A
Laucks Laboratories, Inc. ---------- 3rd cover
Mill Equipment, Inc. ---------- 3rd cover
Soderhamn Machine Mfg. Co. ---------- 27-A
Wilco Machine Works ---------- 29-A
1959 National Meeting ---------- 4-A

SELECTRIC®
sets the pace
in sawyer-operated setworks systems.
FROM 2 TO 30 H.P.
Write for complete information on the system engineered for your production requirements.
• Greater Sawing Accuracy
• Improved Grade Recovery
• Increased Production
• Lower Operating Costs
• Reduced Maintenance Costs
MILL EQUIPMENT INC.
5219 First Ave. South
Seattle 8, Wash.

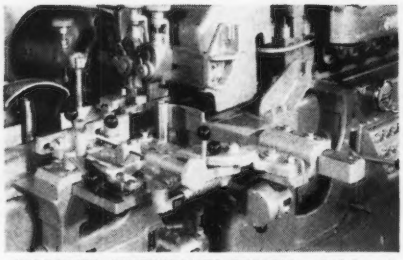

BOOST PRODUCTIVITY AND EFFICIENCY
up to 20% through
100% INSPECTION
WITH
LAUCKS Sentry®
CONTINUOUS MOISTURE DETECTORS
Laucks Sentry Monitor with Brown Electronik Recorder
Sentry systems are recognized as the standard of performance and accuracy in measuring, marking and recording moisture content in plywood, lumber, insulating board and certain granular materials. Positive 100% inspection eliminates time and manpower involved in random testing. If desired, a continuous recorder can be used with the automatic marker to provide a permanent profile of your production.
There's a Sentry system matched to your moisture control requirements. Write for full details.
LAUCKS LABORATORIES, INC.
1201 POPLAR, SEATTLE 44, WASHINGTON
Serving the forest industries over half a century

Here they are!

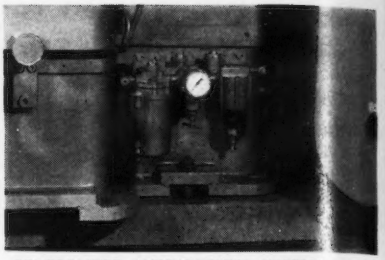
NEW Diehl 5-head moulders



FAST, ACCURATE SET-UP CHANGES — Handwheel, conveniently located at infeed end, lowers and raises bed . . . provides exact depth of cut desired on first bottom head. Locking lever assures complete rigidity of bed in any position.



IMPROVED CHIPBREAKER DESIGN — Sidehead chipbreaker features quick release for set-up and safety. Cam adjustments quickly accommodate a complete range of cutting circles and swings. Rugged construction for all types of heavy work.



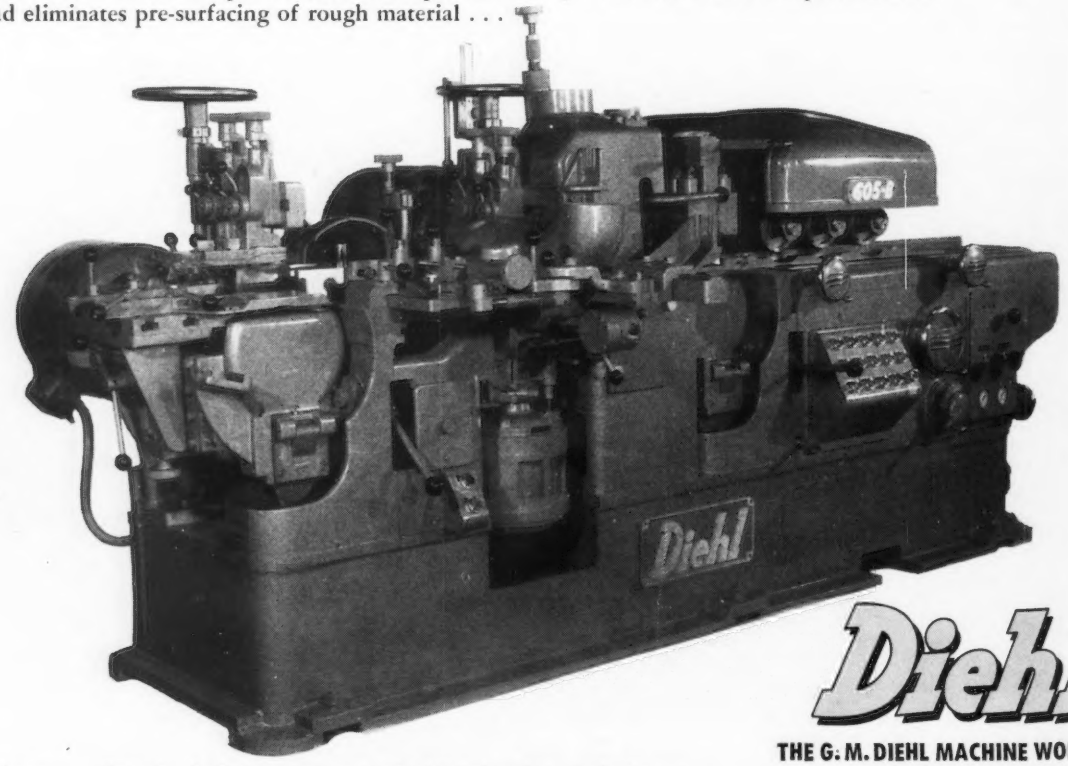
CENTRALIZED LUBRICATION SYSTEM (standard equipment) — Oil-mist spray system lubricates vital parts in feedworks and hopper feed. Works automatically with minimum air pressure. Convenient one tank filling.

. . . designed for speed, accuracy, economy

This new line of 5-Head Moulders gives you all the profit-making features you'd expect from Diehl . . . and then some! It's built for volume production . . . provides the same trouble-free efficiency found in Diehl's famous 4-Head Moulders.

Addition of the fifth cutterhead means greater versatility . . . lets you combine several operations into one. With two bottom heads in operation, for example, the first head eliminates pre-surfacing of rough material . . . yet assures a perfectly smooth, flat surface against the bed. Result: Precision machining at lower operating cost!

The new Diehl 5-head series is available in 6″, 8″ and 12″ sizes with two bottom heads or two top heads as desired. See the complete line of performance-proved Diehl Moulders before you buy . . . there's one that's just right for your operation. Write for bulletin or contact your exclusive Diehl representative.



For 50 Years . . . Standard of Comparison in the Woodworking Industry

Diehl

THE G. M. DIEHL MACHINE WORKS, INC.
WABASH, INDIANA